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MONITORING THE IMPACT OF INTENSIFICATION OF AGRICULTURAL LAND USE ON THE QUALITY OF SOILS OF UKRAINE

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Abstract

The article examines the influence of intensification of agricultural activities on soil quality, the dependence of humus content in soils on the dynamics of the technically available energy potential of crops grown in Ukraine in the regional context, as well as amount of organic fertilizers that can obtain from farm animal. A decrease in the humus content in the soils of Ukraine was established according to the obtained results. It is primarily due to increasing cultivation of soil-depleting crops and reducing the number of farm animals, waste products of which can use to restore land fertility. This situation leads to a loss of natural fertility of agricultural land and a decrease in their monetary value. It will require significant financial costs to further restore the quality characteristics of Ukraine's soils. The paper used a wide range of methods of statistical analysis, grouped administrative regions into clusters according to the study. Research data reveal a high correlation coefficient of the studied indicators within individual territories. The research results are expected to be used to plan the necessary measures to increase the environmental and economic efficiency of the agricultural land use system.

***Key words**: humus level, intensification, energy potential, organic fertilizers, soil quality*

INTRODUCTION

Today, world agricultural production is focused on making a quick profit, despite the effects of anthropogenic impact on the state of the land. First of all, it is manifested in the intensification of the crop sector, which is focused on increasing the sown area under energy crops. This situation is typical for Ukraine too and aims to increase the crop industry's energy potential. Therefore, many scientific publications are devoted to the study of the peculiarities of growing energy crops used for bioenergy production, and their impact on soil fertility. Many scientists around the world are studying the aftereffects of energy crop production on the condition of land used in agriculture.

Thus, in particular, the study of the impact of different energy crops on the condition of soils and the possibilities of their cultivation on individual land plots are devoted to the works of many scientists [11, 13, 14].

Numerous works are devoted to methodological approaches to assessing the potential of energy crops for energy production and social and economic effects [8, 9, 17].

It is important to study [1, 16] in terms of improving the efficiency of economic instruments to reduce the negative human impact on the environment due to the use of products of energy crops. The findings of these studies confirm the importance of developing of the bioenergy industry to achieve positive economic and social results. However, it is defined that due to the increase in sown areas of soil-depleting crops there is an increase in the negative impact of economic activity on the quality parameters of land used in agriculture.

To restore soil fertility, the use of organic fertilizers to fertilize the land and restore the content of humus in the soil plays an important role.

The work of many scientists is devoted to the study of the use of organic fertilizers to improve soil fertility and obtain other environmental effects. Thus, in a study [12] it was substantiated that the introduction of animal manure into the soil promotes plant development, the resistance of herbivores, and the suppression of pests. The need for simultaneous intensive development of the livestock and crop industries to increase soil fertility has been proven in [7].

Practices of organic fertilizer production and soil quality improvement, as well as the relationship between the use of nitrogen and carbon in agricultural activities depending on the organization of waste management of animal and plant origin are widely represented in the study [2].

The practice of the organic fertilizer distribution(manure) depending on the quality characteristics of land and opportunities for the intensification of agricultural activities is studied in [5]. The importance of using manure to intensify the cultivation of crops is emphasized in a study on household development in China [6].

At the same time, the scientific community pays insufficient attention to a comprehensive study of the impact of intensification of crop production (including increased production of soil-depleting crops such as sunflower, soybeans, rapeseed, etc.) and the level of fertilization of land with organic fertilizers from farm animals (the content of humus in them).

Therefore, we hypothesize that there is a close relationship between these parameters to use the identified interdependencies to harmonize environmental and economic interests in the field of agricultural land use at different levels of government.

MATERIALS AND METHODS

The methodological basis of the study is a dialectical approach that allows assessing the effect of economic laws in establishing trends and patterns of social and natural phenomena and processes, to analyze the current state of the agricultural land use system, and suggest ways to improve it.

Important in the system of land-use efficiency assessment is a regionally integrated approach, which allows showing the interdependence of economic and social systems, their inseparable unity with the natural environment, the balance of relations with which forms the principles of environmental safety and sustainable development of land use in agriculture.

In this case, we consider it is important to use the cluster approach as a tool for targeted management of environmental and economic components of the regional system of land use in the agricultural sector. This is crucial in improving the environmental and economic efficiency of agricultural land use. Using the possibilities of clustering, it is assumed to identify areas where there is a significant effect of certain factors. The result is the establishment of priorities for economic development, taking into account its impact on the quality parameters of land.

To assess the level of intensification of land use in the agricultural sector, a study of the dynamics of the technically available energy potential of crops grown in Ukraine in the regional context. In this case, it is proposed to use the "Methods of generalized assessment of technically achievable energy potential of biomass", which was developed by scientists of the National University of Life and Environmental Sciences of Ukraine, Institute of Technical Thermophysics NAS of Ukraine, Institute of Renewable Energy NAS of Ukraine [4].

To determine the possibilities for the fertile layer restoration of soil (humus), which is lost because of growing crops during the analyzed period, it is suggested to investigate the production of organic fertilizers in the process of growing farm animals. The calculation is proposed to be carried out by following the "Methods for calculating the volume of agricultural products at constant prices and the index of agricultural products", which was approved by the order of the State Statistics Service of Ukraine from 19.09.2019 №311 [10].

The results of the research and the impact of the analyzed factors on the level of humus in the soils of Ukraine for the period 1990-2019 were evaluated using the software package Statistica 10.0: the degree of the interrelation of the analyzed indicators was assessed, influence, the clustering of the regions of Ukraine by the degree of interconnection, the unification of the regions into four clusters by the three assessed components.

The information base for the study was materials and reports of the State Statistics Service of Ukraine, the Institute of Soil Protection of Ukraine, guidelines for research of scientific, educational, and government agencies, publications of domestic and foreign scientists, as well as author's work on the issue.

RESULTS AND DISCUSSIONS

Deterioration of the ecological condition of land in the process of its agricultural use is an urgent problem in the modern world. This trend we can also observe in Ukraine. This is confirmed by the following study [15], in which the authors highlight the importance of taking into account environmental factors (level of land plowing, environmental stability, land pollution, development of degradation processes, etc.) in the process of organizing efficient agricultural land-use.

The article displays that the identification of environmental threats and risks will allow modeling measures to combat the impact of eco-destructive factors and form a mechanism for their implementation. This will have a positive impact on the state of agricultural land-use. Therefore, to identify eco-destructive factors in the system of agricultural land use, we propose to investigate the impact on soil quality of land use intensification in agriculture (by assessing the technically available energy potential obtained by growing crops in Ukraine), as well as to assess volumes of production of organic fertilizers in the process of growing farm animals. The results you can use to determine the possibility of restoring the humus content in soils.

According to the analysis of soil quality indicators by organic component (humus content) revealed a gradual decrease in the level of humus for the period 1990-2019. The dynamics of reducing the humus content on agricultural lands is noted in the following administrative regions of Ukraine: Cherkasy, Chernivtsi, Kharkiv, Khmelnitskyi, Luhansk, Mykolaiv, Poltava, Ternopil, Vinnytsia, Volyn. Thus, over the past 25 years, the average humus content in Ukraine has decreased by 0.12 percent. This is a significant loss because of increasing it in the soil for 0.1 percent in natural conditions requires 25-30 years [3].

Among the factors that caused this deterioration of soil quality is the impact of agricultural intensification activities. This process is accompanied by an increase in the structure of sown areas of those crops whose products can be used for bioenergy production and which in the process of development mineralize much more humus in the soil than the remaining organic matter after harvest (it is then used to fertilize land by its plowing).

The increase in the share of soil-depleting crops per 100 hectares of arable land is also evidenced by the growth of technically achievable energy potential of cultivated crops (Table 1).

In some regions (Zaporizhia, Herson, and Chernihiv regions) the growth occurred more than 10 times.

The situation is complicated by the fact that during the analyzed period in Ukraine, there was also a significant reduction in the number of farm animals. This has reduced the production of manure, which you can use to restore the humus content in the soil.

Table 1. Volumes of technically achievable energy potential per 100 hectares of arable land, which can be obtained from agricultural raw materials produced in Ukraine in the regional context for 1990-2019 (tons of conventional fuel per 100 hectares of arable land)

Region	Years								
	1990	2000	2010	2012	2014	2016	2017	2019	2019/ 1990,%
Cherkasy	4.2	1.8	6.4	9.9	10.2	9.2	7.8	12.6	300.0
Chernihiv	1.1	0.7	3.6	7.2	8.3	6.6	9.6	11.4	1,036.4
Chernivtsi	4.6	2.8	4.6	5.7	8.2	4.1	6.1	6.9	150.0
Dnipropetrovsk	0.9	0.9	1.9	1.4	3.3	3.3	4.0	7.7	855.6
Donetsk	0.4	0.4	0.5	0.5	1.2	0.6	1.5	2.2	550.0
Herson	0.4	0.3	3.1	0.8	2.4	1.9	3.7	5.3	1,325.0
Ivano-Frankivsk	2.6	1.7	3.2	8.0	11.7	8.6	13.1	10.4	400.0
Kharkiv	1.7	0.9	1.0	2.5	3.8	3.4	3.0	2.9	170.6
Khmelnytskyi	3.9	1.6	6.2	8.6	13.1	8.2	10.7	13.6	348.7
Kirovohrad	2.1	1.0	4.7	3.7	6.0	5.4	5.1	7.9	376.2
Kyiv	2.9	1.4	3.8	8.0	9.4	6.7	6.9	11.7	403.4
Luhansk	0.3	0.4	0.3	0.7	0.9	0.8	0.5	0.7	233.3
Lviv	2.9	1.4	6.8	9.3	11.7	8.8	12.2	13.2	455.2
Mykolayiv	0.8	0.3	3.4	1.1	3.2	1.4	2.5	5.8	725.0
Odesa	0.9	0.6	6.3	1.2	6.1	2.5	6.2	8.7	966.7
Poltava	3.3	1.3	4.3	6.5	7.3	8.7	6.5	9.4	284.8
Rivne	3.3	1.1	4.6	6.6	7.7	5.0	7.1	10.9	330.3
Sumy	2.9	0.8	3.1	6.4	8.9	7.0	7.9	9.7	334.5
Ternopil	4.5	2.2	8.0	10.5	14.1	9.8	12.8	15.8	351.1
Transcarpathian	1.6	1.6	2.8	3.2	3.2	4.4	4.2	4.3	268.8
Vinnytsia	4.1	2.3	5.6	7.5	12.4	8.6	10.8	13.4	326.8
Volyn	2.3	1.0	3.6	5.1	7.4	4.8	8.4	12.4	539.1
Zaporizhia	0.3	0.3	1.4	0.4	1.2	1.2	1.5	3.9	1,300.0
Zhytomyr	1.2	0.5	2.5	5.6	6.5	4.8	6.4	10.4	866.7
Ukraine	**1.9**	**1.0**	**3.5**	**4.2**	**6.1**	**4.6**	**5.7**	**8.0**	**421.1**

Source: calculated according to the State Statistics Service of Ukraine.

Thus, the volume of production of organic fertilizers per 1 ha of arable land decreased the most in Luhansk, Mykolaiv, and Zaporizhia regions - in the range of 9.7-16.5 times (Table 2).

To establish the interdependence between the indicators of the obtained technically achievable energy potential of crops per 100 hectares of arable land and the level of humus in soils, we studied the correlation dependence of the dynamics of these indicators in terms of regions of Ukraine.

As a result of the analysis, the regions where there is the closest connection of these indicators (correlation coefficient greater than 0.8) were identified. Thus, the greatest direct connection is observed between the dynamics of indicators of technically achievable potential of agricultural sowing and the level of humus in the following regions: Transcarpathian (0.88) and Kyiv (0.86) regions. We note the inverse connection in Luhansk (-0.83), and Kharkiv (-0.85) regions. This is evidence of the intensification of agricultural activities in these administrative areas.

The interdependence of humus content in soils on the dynamics of organic fertilizer production is greatest in the following regions: Khmelnytskyi (0.92), Lviv (0.90), Mykolaiv (0.92), Poltava (0.97), Vinnytsia (0.88) and Volyn (0.98), region. The closeness of the connection of these indicators in Ukraine, in general, is also quite significant (the correlation coefficient is 0.98).

The inverse connection between these indicators is noted in the Chernihiv region (-0.98). The explanation for this may be a significant increase in sown areas of depleting crops (sunflower and soybeans) with a significant reduction in the application of organic fertilizers to improve the quality of land (in this region, they are characterized by low humus content).

Table 2. Volumes of organic fertilizers per 1 ha of arable land that can be obtained from farm animals in terms of regions of Ukraine, t per 1 ha of arable land

Region	Years								
	1990	**2000**	**2010**	**2012**	**2014**	**2016**	**2017**	**2019**	2019/1990,%
Cherkasy	7.7	3.5	2.4	2.4	2.2	2.0	1.9	1.8	23.4
Chernihiv	9.9	3.6	1.9	1.9	1.6	1.5	1.4	1.2	12.1
Chernivtsi	13.5	6.1	4.2	4.1	3.5	3.2	3.1	3.0	22.2
Dnipropetrovsk	6.2	1.8	1.1	1.1	1.1	1.0	0.9	0.9	14.5
Donetsk	6.7	2.1	1.4	1.4	1.0	0.7	0.8	0.8	11.9
Herson	5.4	1.4	0.8	0.9	0.9	0.8	0.7	0.6	11.1
Ivano-Frankivsk	14.1	8.1	5.5	5.6	5.2	4.8	4.5	4.2	29.8
Kharkiv	6.6	2.4	1.2	1.2	1.2	1.1	1.1	1.0	15.2
Khmelnytskyi	9.0	4.5	2.4	2.4	2.2	2.1	2.1	2.0	22.2
Kirovohrad	5.1	1.5	0.9	0.9	0.8	0.7	0.7	0.6	11.8
Kyiv	9.5	3.4	1.9	2.0	1.9	1.8	1.8	1.8	18.9
Luhansk	6.6	1.8	1.1	1.0	0.6	0.4	0.4	0.4	6.1
Lviv	13.7	7.5	4.0	4.0	3.6	3.4	3.3	2.9	21.2
Mykolayiv	4.9	1.4	0.9	0.9	0.8	0.8	0.9	0.5	10.2
Odesa	5.6	2.3	1.3	1.3	1.3	1.1	1.0	0.9	16.1
Poltava	7.3	2.8	1.6	1.7	1.6	1.5	1.4	1.3	17.8
Rivne	12.2	5.8	3.7	3.8	3.3	3.0	2.9	2.4	19.7
Sumy	7.8	3.4	1.5	1.5	1.3	1.3	1.3	1.2	15.4
Ternopil	10.3	4.6	2.6	2.8	2.5	2.4	2.2	2.1	20.4
Transcarpathian	18.9	10.3	9.0	9.2	8.6	8.0	7.7	8.0	42.3
Vinnytsia	7.4	3.4	2.1	2.2	2.1	2.2	2.1	1.8	24.3
Volyn	13.7	6.1	4.0	4.1	3.6	3.4	3.2	2.8	20.4
Zaporizhia	5.8	1.5	0.8	0.8	0.8	0.7	0.7	0.6	10.3
Zhytomyr	10.0	4.8	2.3	2.3	1.9	1.9	1.9	1.9	19.0
Ukraine	**7.4**	**2.9**	**1.7**	**1.7**	**1.5**	**1.5**	**1.4**	**1.3**	**17.6**

Source: calculated according to the State Statistics Service of Ukraine.

The cluster analysis of the regions of Ukraine was carried out in the program Statistica 10.0. In each of the clusters for the period, 1990-2019 (data for 1990, 2000, 2010, and 2019 were used for the study) similar properties of the following indicators were taken into account: the volume of the technically achievable energy potential of cultivated crops, the volume of production of organic fertilizers and the content of humus in the soil. The results of cluster analysis in the division of regions of Ukraine into 4 clusters are given in Tables 3 and 4.

Table 3. The results of the cluster analysis of the regions of Ukraine for 1990, 2000, 2010, and 2019 are based on the grouping of the studied indicators that affect the quality of soils

Years	Cluster characteristics (administrative areas)			
	First	Second	Third	Fourth
1990	Chernivtsi, Ivano-Frankivsk, Lviv, Rivne, Transcarpathian, Volyn	Cherkasy, Chernihiv, Khmelnytskyi, Kyiv, Poltava, Sumy, Ternopil, Vinnytsia, Zhytomyr	Dnipropetrovsk, Donetsk, Kharkiv, Luhansk	Herson, Kirovohrad, Mykolayiv, Odesa, Zaporizhia,
2000	Cherkasy, Chernihiv, Khmelnytskyi, Kyiv, Poltava, Sumy, Ternopil, Vinnytsia, Zhytomyr	Chernivtsi, Ivano-Frankivsk, Lviv, Rivne, Transcarpathian, Volyn	Herson, Kirovohrad, Mykolayiv, Odesa, Zaporizhia	Dnipropetrovsk, Donetsk, Kharkiv, Luhansk
2010	Chernihiv, Herson, Kirovohrad, Kyiv, Mykolayiv, Poltava, Sumy, Zhytomyr	Dnipropetrovsk, Donetsk, Kharkiv, Luhansk, Zaporizhia	Cherkasy, Khmelnytskyi, Lviv, Odesa, Ternopil, Vinnytsia	Chernivtsi, Ivano-Frankivsk, Rivne, Transcarpathian, Volyn
2019	Chernivtsi, Dnipropetrovsk, Herson, Kirovohrad, Mykolayiv, Odessa, Poltava, Sumy	Cherkasy, Chernihiv, Ivano-Frankivsk, Khmelnytskyi, Kyiv, Lviv, Rivne, Ternopil, Vinnytsia, Volyn, Zhytomyr	Transcarpathian	Donetsk, Kharkiv, Luhansk, Zaporizhia

Source: calculated by the authors.

Table 4. Average values of quantitative indicators of the volume of the technically achievable energy potential of crops, organic fertilizers, and humus content according to the results of cluster analysis of the regions of Ukraine in 1990, 2000, 2010, and 2019 based on the grouping of studied indicators that affect the quality status soils

Name quantitative indicators	Numerical characteristics of clusters (average values of quantitative indicators (standard deviations))			
	First	Second	Third	Fourth
1990 year				
Organics	14.35 (2.32)	8.77 (1.22)	6.53 (0.22)	5.36 (0.36)
Potential	2.88 (1.02)	3.12 (1.25)	0.83 (0.64)	0.9 (0.72)
Humus	2.34 (0.42)	2.92 (0.53)	4.18 (0.29)	3.33 (0.73)
2000 year				
Organics	3.78 (0.68)	7.32 (1.72)	1.65 (0.44)	1.92 (0.34)
Potential	1.40 (0.64)	1.60 (0.65)	0.38 (0.15)	0.72 (0.29)
Humus	2.84 (0.49)	2.38 (0.58)	3.01 (0.58)	4.14 (0.21)
2010 year				
Organics	1.48 (0.56)	1.12 (0.22)	2.47 (0.88)	5.28 (2.19)
Potential	3.56 (0.70)	1.02 (0.65)	6.55 (0.81)	3.76 (0.82)
Humus	2.97 (0.70)	3.99 (0.37)	2.98 (0.29)	2.33 (0.54)
2019 year				
Organics	1.13 (0.81)	2.26 (0.80)	8.00 (0.00)	0.7 (0.26)
Potential	7.68 (1.60)	12.35 (1.62)	4.30 (0.00)	2.43 (1.35)
Humus	3.32 (0.70)	2.68 (0.53)	2.56 (0.00)	3.69 (0.32)

Source: calculated by the authors.

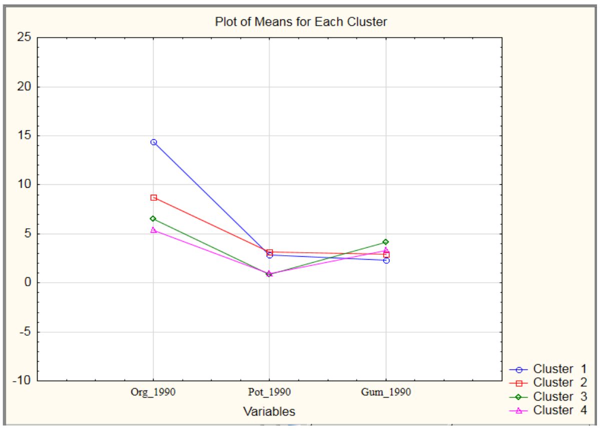

Fig. 1. Graphic representation of averages for each cluster in 1990
Source: calculated by the authors.

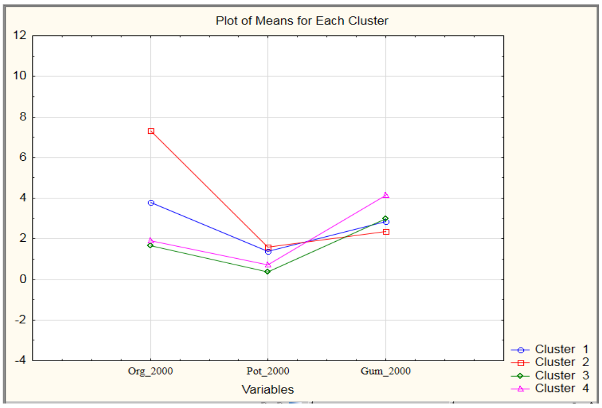

Fig. 2. Graphic representation of averages for each cluster in 2000
Source: calculated by the authors.

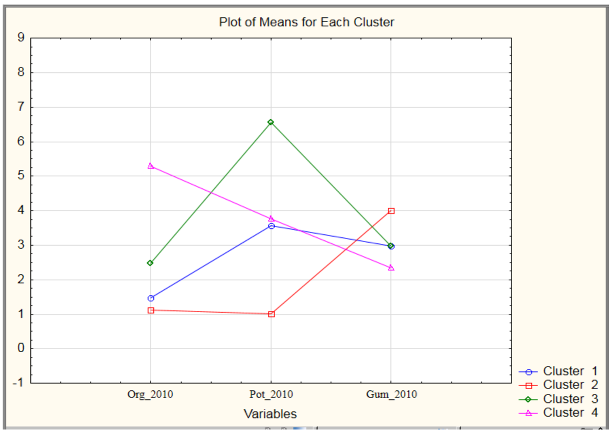

Fig. 3. Graphic representation of averages for each cluster in 2010
Source: calculated by the authors.

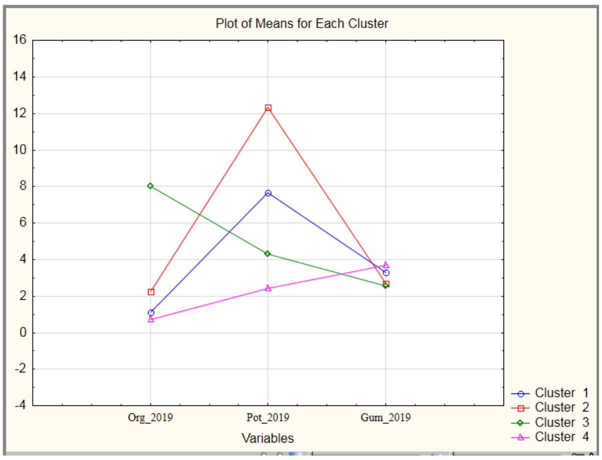

Fig. 4. Graphic representation of averages for each cluster in 2019
Source: calculated by the authors.

The correct choice of the number of clusters is confirmed by analysis of variance because at the level of significance $p < 0.05$ we have differences between the obtained groups.

In fig. 1-4 shows the results of cluster analysis (C-average method) in some years for the period 1990-2019 in the form of division of regions into four clusters by three components (the amount of technically achievable energy potential of crops, the amount of organic fertilizers and the level of humus in soils).

Based on the presented figures, we observe the relationship between the studied groups of indicators. Thus, during the analyzed period in all clusters the highest average indicators for the production of organic fertilizers (manure) and technically achievable energy potential of crops correspond to one of the lowest average indicators of humus content in soils, and vice versa. This may indicate limited use of organic matter to improve soil quality, as well as an increased intensification of agricultural activities. The consequence is the depletion of agricultural land. In addition, in 2010-2019, we note a significant increase in the volume of technically achievable energy potential in the 3rd and 2nd clusters. It indicates an increase in the production of energy-intensive agricultural products, especially in the administrative regions, which are located in the West, North, and centre of Ukraine, and affects the quality of soils (humus content) in these regions.

According to the results of the study, it should be noted that in most regions of Ukraine there is an inverse connection between the humus content in soils and the intensification of agricultural land use. This determines the relevance of further balancing the anthropogenic impact on the state of land and determining the directions of development of agricultural land use. They will be aimed at taking into account the dynamics of humus content in soils in the process of optimizing the structure of sown areas of crops and the formation of an appropriate system of organic fertilizers. To ensure of balanced use land at the national level, it is crucial to form a set of legislative acts that will be aimed at exercising appropriate administrative influence on land users, whose actions lead to the deterioration of the quality of agricultural land.

Therefore, it is important to increase soil fertility to organize a system of balanced land use, aimed at improving the efficiency of agricultural land use.

CONCLUSIONS

The study makes it possible to argue that the monitoring and consideration of the interaction of the two subsystems of natural and economic on the quality of land is crucial for the formation of a system of balanced agricultural land use. The analysis installed the relationship between the intensification of agricultural activities, the level of production of organic fertilizers, and the quality of land (humus content in soils).

Using the data of statistical processing in the program Statistica 10.0 of the studied indicators, a significant level of interdependence and clustering of the regions of Ukraine in the period 1990-2019 was revealed.

Further study of the impact of regulatory factors of a balanced natural economic system will identify positive measures to improve soil fertility and reduce the impact of negative anthropogenic factors on the quality parameters of agricultural land.

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