Analysis and Prediction of Humus Balance in Soils of Ukraine Using Informational Tools

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Abstract

The impact of agricultural activity intensification on soil quality, the relationship between soil humus content and the dynamics of the technically feasible energy potential of crops grown in Ukraine in the regional context, and the production of organic fertilizers as a result of raising livestock are all topics covered in this article. The investigation revealed a downward trend in the humus content of Ukrainian soils, which is mostly attributable to an increase in the production of crops that deplete the soil and a decrease in the production of organic fertilizers, which can be used to restore land fertility. Due to this circumstance, agricultural land loses its inherent fertility and its monetary value. To further rehabilitate it, enormous financial resources will be needed. The paper used a wide range of methods of analysis and mathematical modeling, grouped administrative regions into clusters according to the study. Research data reveal a high correlation coefficient of the studied indicators within individual territories. Crop rotation modeling and percentages of organic fertilizer application will be made possible by the integration of IT technologies, using the example of a humus balance e-calculator for organic land use, in order to stabilize or improve soil quality. 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.

Keywords 1

humus balance, modeling, organic portal, organic fertilizers, soil quality

1. Introduction

Despite the impacts of anthropogenic impact on the state of the soil, the goal of modern agricultural production is to turn a quick profit. It first appears in the intensification of the crop sector, which is geared toward expanding the area sown with energy crops. This circumstance, which is typical of Ukraine as well, strives to boost the energy potential of the crop industry. The characteristics of growing energy crops used for bioenergy generation and their impact on soil fertility are therefore the subjects of several scholarly papers. Numerous researchers are looking into how the development of energy crops affects the state of agricultural land [1].

Methodological approaches to evaluating the potential of energy crops for energy production and their social and economic implications are the subject of numerous works [2, 3].

The outcomes of this research generally provide the basis for the claim that the growth of the bioenergy sector is crucial for obtaining a variety of social and economic benefits. However, it is

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known that there is a growing negative influence of economic activity on the quality parameters of land used for agriculture as a result of the growth in seeded areas of soil-depleting crops.

The application of organic fertilizers to feed the soil and replenish its humus content is crucial for restoring soil fertility. The study of the application of organic fertilizers to increase soil fertility and acquire other environmental impacts is the focus of the work of many scientists. Accordingly, it was proven in a study [4] that adding animal dung to the soil encourages plant growth, herbivore tolerance, and the control of pests. Paper [5] illustrates the significance of the development of the livestock industry working in tandem with crop production to enhance the quality qualities of land.

The phrase "humus balance" refers to both the model for maximizing soil productivity in arable land by calculating the demand for organic fertilizers without quantifying the change in SOM or SOC, as well as simple models for quantifying changes in soil organic matter (SOM) or soil organic carbon (C) (SOC) in arable soils [6–8]. Several scientists have been working on humus balance modelling, mass, heat and moisture transfer in soils at the same time. [7–19]. They established the fundamental terms and guidelines for computing the humus balance.

In turn, predicting humus balance requires the development of compartment-type models of reaction-diffuse type, the dynamics of which were studied in [20, 21]. A deeper study of the interaction of counterparts within such type models can be based on recurrent neural networks, the convergence of which was studied in the general case in [22].

The study [23] extensively covers the use of various methods for obtaining enough organic fertilizers and maintaining soil fertility, as well as the relationship between nitrogen and carbon efficiency depending on the development of various novel methods for the treatment of plant residues and animal waste.

At the same time, the scientific community gives insufficient consideration to a thorough investigation of the effects of crop intensification (including increased production of crops that deplete the soil, such as sunflower, soybeans, rapeseed, etc.) and the amount of land fertilized with organic fertilizers from farm animals (the content of humus in them) [24].

To leverage the identified interdependencies to harmonize environmental and economic interests in the area of agricultural land use at various levels of government, we predict that there is a close relationship between these characteristics.

In addition, many scientists have emphasized that an important factor in the effectiveness of agricultural production development, including organic production, is the introduction of innovative management approaches based on software complexes and geoinformation systems (GIS) [25–29]. Features of GIS use in the agricultural sector, including organic farming, presented by such scientists as: Medvedev V. V. [30], Romashchenko M. I.[31], Morozov V. V. [32], Pichura V. I. [1], JaafarH. H. [33], Montgomery B. [34], Mishra A. K. [35], Pilehforooshha P. [36] and other scientists. However, as of right now, Ukraine has no expertise in developing websites, portals, or software for online modelling the humus content change over time.

2. Materials and Methods

The study's methodology is based on a dialectical approach, which enables analysis of the current state of the agricultural land use system and recommendations for its improvement. This approach allows for assessing the impact of economic laws in establishing trends and patterns of social and natural phenomena and processes.

A regionally integrated approach, which demonstrates the interdependence of economic and social systems, their unbreakable unity with the natural environment, and the balance of relationships with which the principles of environmental safety and sustainable development of land use in agriculture are formed, is crucial to the system of land-use efficiency assessment.

In this situation, we believe it is crucial to employ the cluster approach as a tool for the targeted management of the economic and environmental aspects of the regional land use system in the agricultural sector. This is essential for increasing the agricultural land use's economic and environmental efficiency. The goal is to locate regions where specific factors have a noticeable impact by using clustering's potential. As a result, economic development priorities are established, taking into account how they will affect the standards of land quality.

A study of the dynamics of the technically feasible energy potential of crops cultivated in Ukraine in the regional context is necessary to determine the degree of intensification of land use in the agricultural sector. 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 [37].

It is advised to look into the creation of organic fertilizers during the process of raising farm animals in order to assess the possibilities for the fertile layer restoration of soil (humus), which is lost due to growing crops during the examined period. 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.

Using the software program Statistica 10.0, the study's findings and the effects of the factors considered on the amount of humus in Ukraine's soils from 1990 to 2019 were assessed. The interrelation between the factors considered was evaluated, as well as their influence, the degree of interconnection among the factors considered, the clustering of the country's regions, and the division of the regions into four clusters based on the three factors considered.

Materials and reports from the State Statistics Service of Ukraine, the Institute of Soil Protection of Ukraine, and research guidelines from scientific, educational, and governmental organizations used as the study's data source.

3. Results and Discussions

An urgent issue in the modern world is the degradation of the ecological condition of land throughout the process of its agricultural usage. We can see this pattern in Ukraine as well.

The paper demonstrates how identifying environmental hazards and threats paves the way for modelling countermeasures to eco-destructive forces and creating a framework for their implementation. The usage of agricultural land will improve as a result of this. Therefore, we propose to investigate the impact of land use intensification in agriculture on soil quality (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, in order to identify eco-destructive factors in the system of agricultural land use. You can use the findings to decide whether it would be possible to increase the humus content of soils.

3.1. Cluster Analysis

According to an analysis of soil quality indicators by organic component (humus content), humus levels gradually declined between 1990 and 2019 in accordance with the indicators. Cherkasy, Chernivtsi, Kharkiv, Khmelnitskyi, Luhansk, Mykolaiv, Poltava, Ternopil, Vinnytsia, and Volyn are some of the administrative regions of Ukraine where the dynamics of diminishing the humus content on agricultural fields have been observed. So, in Ukraine, the average humus content has fallen by 0.12% over the past 25 years. Due to the fact that it takes 25–30 years to naturally increase it by 0.1 percent in the soil [38].

The effects of agricultural intensification activities are one of the elements that contributed to this degradation of soil quality. This process is accompanied by a change in the structure of the areas where crops that can produce bioenergy are seeded. These crops mineralize significantly more humus in the soil during development than the soil still contains after harvest (it is then used to fertilize land by its plowing).

The rise in the technically feasible energy potential of cultivated crops is another indicator of the rise in the proportion of soil-depleting crops per 100 hectares of arable land (check Table 1). The growth was greater than ten times in some regions (Zaporizhia, Herson, and Chernihiv).

The fact that there was a large decline in the number of farm animals in Ukraine throughout the studied period further complicates the matter. Due to this, there is less manure being produced, which you can utilize to replenish the humus in the soil. Thus, in the Luhansk, Mykolaiv, and Zaporizhia areas, the volume of production of organic fertilizers per 1 hectare of arable land reduced by 9.7 to 16.5 times. We investigated the correlation dependence of the dynamics of these indicators in terms of regions of Ukraine in order to establish the interdependence between the acquired technically attainable energy potential of crops per 100 hectares of arable land and the degree of humus in soils.

The study led to the identification of the areas where these indicators are most closely related (correlation coefficient > 0.8). As a result, the Transcarpathian (0.88) and Kyiv (0.86) regions show the most direct correlation between the dynamics of indicators of technically possible capacity of agricultural sowing. We observe the inverse relationship in the Kharkiv (-0.85) and Luhansk (-0.83) regions. This demonstrates how agricultural operations have become more intensive in different administrative regions.

The following regions have the highest levels of interdependence between soil humus content and the kinetics of organic fertilizer production: Khmelnytskyi (0.92), Lviv (0.90), Mykolaiv (0.92), Poltava (0.97), Vinnytsia (0.88), and Volyn (0.98). Additionally important is how closely these variables relate to one another across the board in Ukraine (the correlation coefficient is 0.98).

Table 1

Volumes of technologically possible energy potential per 100 hectares of agricultural land that can be acquired from agricultural raw materials produced in Ukraine in the context of the region for 1990–2019 (tons of conventional fuel per 100 hectares of arable land)

Region	Years								
	1990	**2000**	**2010**	**2012**	**2014**	**2016**	**2017**	**2019**	**The ratio of 2019 to 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	1036.4
Chernivtsi	4.6	2.8	4.6	5.7	8.2	4.1	6.1	6.9	150.0
Dnipro	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	1325.0
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
Kropyvnytskyi	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	1300.0
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**

In the Chernihiv region, it is observed that these indicators have an inverse relationship (-0.98). This could be explained by a considerable increase in the areas of depleting crops (such as sunflower and soybeans) that are sown alongside a significant decrease in the use of organic fertilizers to improve the condition of the soil (in this region, they are characterized by low humus content).

Applying the software Statistica 10.0, the regions of Ukraine were exposed to cluster analysis. The volume of the technically attainable energy potential of cultivated crops, the volume of production of organic fertilizers, and the content of humus in the soil were taken into consideration in each cluster during the period 1990–2019 (data for 1990, 2000, 2010, and 2019 were utilized for the study). The table below lists the findings of the cluster analysis used to divide Ukraine's regions into 4 clusters (Tables 3, 4).

Table 2

Volumes of organic fertilizers produced by farm animals per 1 ha of arable land in each area of Ukraine, measured in t per ha of agricultural land

Region	Years								
	1990	**2000**	**2010**	**2012**	**2014**	**2016**	**2017**	**2019**	The ratio of 2019 to 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
Dnipro	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
Kropyvnytskyi	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**

Table 3

The results of the Ukraine regions cluster analysis for 1990, 2000, 2010, and 2019 based on the studied indicators grouping that affects 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	Dnipro, 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, Lviv, Khmelnytskyi, Odesa, Ternopil, Vinnytsia	Chernivtsi, Ivano-Frankivsk, Rivne, Transcarpathian, Volyn
2019	Chernivtsi, Dnipropetrovsk, Herson, Kropyvnytskyi, Mykolayiv, Odessa, Poltava, Sumy	Cherkasy, Chernihiv, Ivano-Frankivsk, Khmelnytskyi, Kyiv, Lviv, Rivne, Ternopil, Vinnytsia, Volyn, Zhytomyr	Transcarpathian	Donetsk, Kharkiv, Luhansk, Zaporizhia

Analysis of variance shows that the number of clusters was correctly chosen because there are differences between the groups we obtained at a significance level p 0.05.

The findings of cluster analysis (k-means clustering) for various years between 1990 and 2019 are represented in Fig. 1-4 as the split of regions into four clusters by three components (the amount of technically achievable energy potential of crops, the number 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. Additionally, we observe a notable rise in the amount of technically feasible energy potential in the third and second clusters between 2010 and 2019. It implies a rise in the production of agricultural goods that require a lot of energy, particularly in the administrative regions of Ukraine's west, north, and centre. This has an impact on the humus content of the soils in these areas.

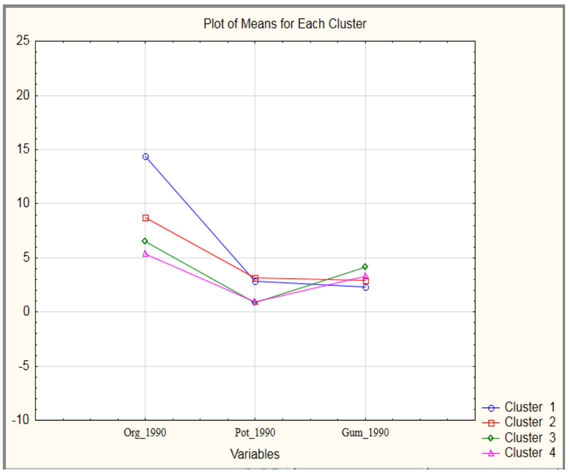
Table 4

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

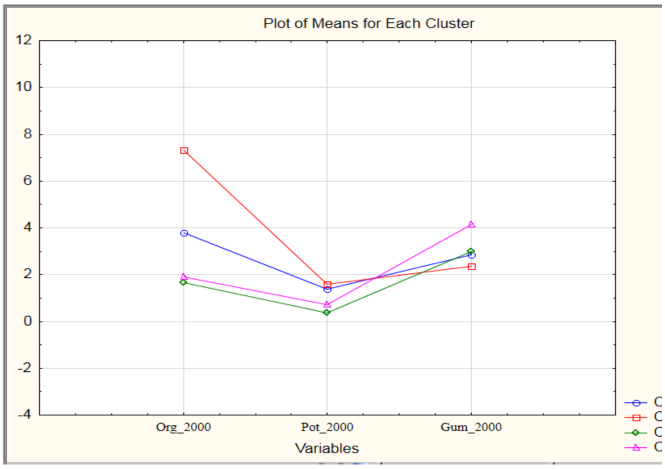
Name quantitative indicators	Numerical characteristics of clusters (average values of quantitative indicators (standard deviations))			
	First	Second	Third	Fourth
1990 year				
Organics	14.35 (2.32)	8.77 (1.22)	6.53 (0.22)	5.36 (0.36)
Potential	2.88 (1.02)	3.12 (1.25)	0.83 (0.64)	0.9 (0.72)
Humus	2.34 (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)

The study's findings indicate that there is, in the majority of Ukraine's regions, a negative relationship between soil humus content and the expansion of agricultural land use. This establishes the necessity of further balancing the effects of human activity on the state of the land and identifying the future directions for agricultural land use. They will be designed to optimize the layout of crop-sown regions and the creation of a suitable system of organic fertilizers while taking into consideration the dynamics of humus content in soils. The creation of an appropriate legislative framework that will guarantee the application of suitable administrative influence on land users is also crucial for the construction of a system of balanced agricultural land use at the national level.

As a result, creating a comprehensive system of balanced land use is essential for raising the quality of agricultural land while also increasing its economic and environmental effectiveness.



a) year 1990



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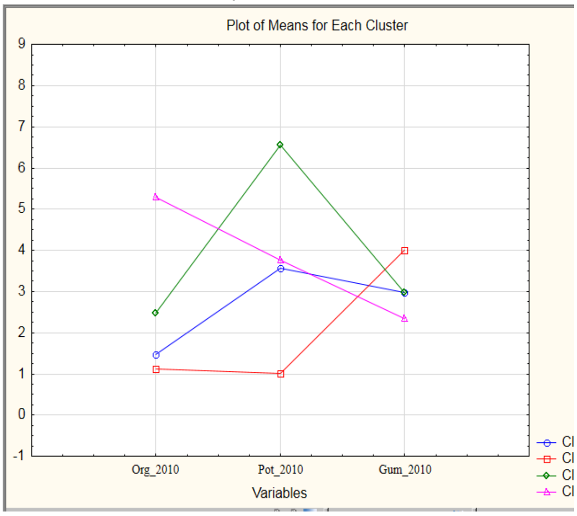
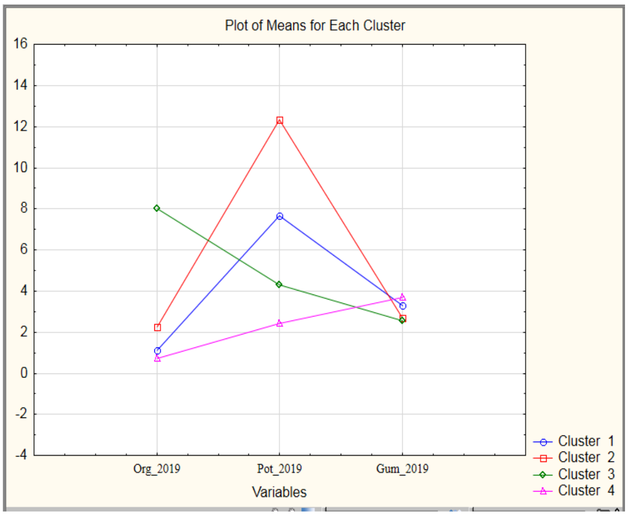


c) year 2010



d) year 2019

Figure 1: Cluster analysis results (K-means method) for the period 1990-2019 for each cluster: blue line – first cluster, orange line – second cluster, green line – third cluster, red line – fourth cluster

3.2. Mathematical Modeling

In order to predict the change in soil organic matter (SOM) levels over a long period, the dynamics of organic matter are simulated. The first published model of OPE decomposition based on differential equations was proposed by S. Genin and his colleagues [39]. One of the most popular SOM dynamics models today is Rothamsted (RothC), which emits 4 active pools and 1 stable pool (inert organic matter) [39]. In the post-Soviet space, the widespread model of ORU dynamics (ROMUL) involves the allocation of three major pools - detritus (prehumus fraction), labile humus, and stable humus [40].

The following paragraph explains the mathematical model of the change in humus concentration in some soil volume [41]:

Let $y(t)$ be the amount of humus at time t (t / ha); $y(t+\Delta t)$ – s the amount of humus at time $t+\Delta t$; at the initial time $y(0)=y_0$, where y_0 – is the amount of humus at the initial time; $f(R,\delta)$ – is some function of the humus balance and the type of crop (t / ha); R – type of culture for planting, δ – balance of humus.

Then the humus change is proportional to the amount of humus at a given time and the function of the humus balance and the type of culture

$$V\frac{y(t+\Delta t)-y(t)}{\Delta t}=V\cdot k\cdot(y(t)+f(R,\delta)),$$

where *k*– some proportionality factor.

At $\Delta t\to 0$, we will get $\frac{dy}{dt}=k\cdot(y(t)+f(R,\delta))$. Then: $\frac{dy}{y(t)+f(R,\delta)}=kdt$

From which $\ln|y(t)+f(R,\delta)|=kt+c$, where $c=const$.

Then: $y(t)=c_1\cdot e^{k\cdot t}-f(R,\delta)$, where $c_1=e^c$.

From the initial condition $y(0)=y_0$ we will get $c_1=y_0+f(R,\delta)$.

Therefore, the humus content at time t is equal to

$$y(t)=(y_0+f(R,\delta))\cdot e^{k\cdot t}-f(R,\delta).$$

By using certain input data as input for this mathematical model, we obtain a graph of the humus content versus time. (Fig. 2).

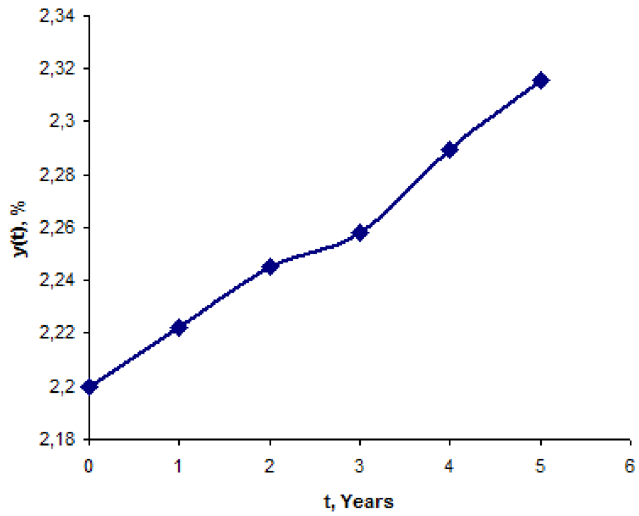


Figure 2: Modeling the dynamics of soil humus content using a mathematical model

3.3. Information-Analytical System

As part of the software implementation work, the aforementioned computer simulation method for affecting the humus condition at a predefined time interval was implemented, accounting for the costs of applying organic fertilizer in the form of an e-calculator. Integration of the newly designed module into the current information-analytical system of organic agriculture was a crucial next step.

The e-calculator module is divided into two sections: the Frontend section and the Backend section, which includes ASP.NET MVC code, average crop fertility statistics, agrochemical soil indicators, etc (html, css, java script). According to the GET and POST requests from the Frontend portion, the Backend part implements the Web API method for numerical calculations. On the client's end, crop rotation, desired crops, and fertilizer opportunities are developed in accordance with the client's needs. The humus state change can be modeled in two different ways: "Individual plan" and "Rationale for all scenarios". By toggling the desired tab in the GUI dialog box for the GUI module, the desired mode can be chosen.

The user selects the crops and the amount of fertilizer for each year in the "Individual plan" mode (Fig. 3). The system will then produce a humus status change report for this specific circumstance utilizing a server-side numerical computation in accordance with the aforementioned mathematical model when the user clicks the "Get Recommendations" button. Instead, the "Rationale for all scenarios" mode includes an automated computation to support any conceivable situation involving fertilizer in various years (Fig. 4). The user can set the amount of funds available for the cost of organic fertilizer and the number of years to examine. Then, using the "Calculate all choices" button, the e-calculator launches the proper algorithm for computer simulation and eco-economic calculations. The user will then be able to select the option that best suits him in terms of cost and environmental impact.

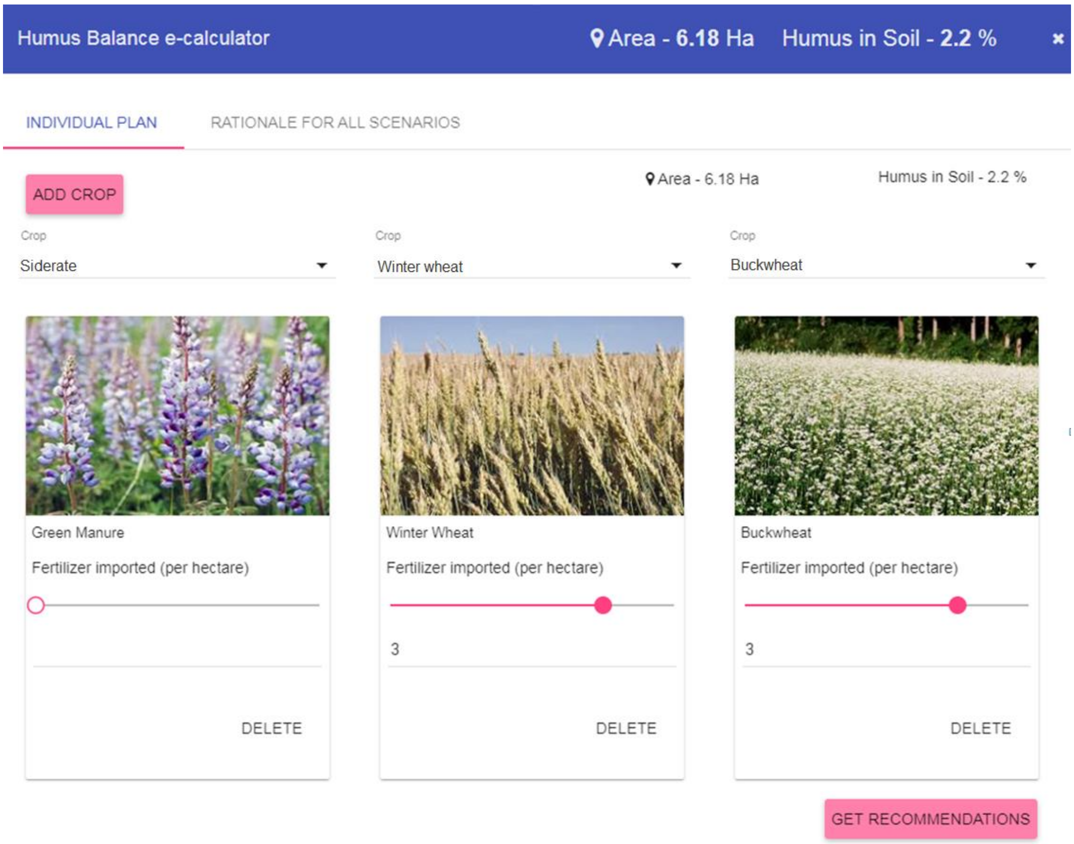


Figure 3: Dialog box for humus change simulation initialization in an individual plan scenario

Figure 4: Dialog box for justification different scenarios involving fertilizer in various years

4. Conclusions

The study's findings support the notion that it is prudent to consider the impact on the status of land characteristics of the operation of the two subsystems of natural and economic in order to ensure the balanced use of land resources by the agricultural sector. The results of the investigation showed a connection between the intensification of agricultural operations, the volume of organic fertilizer production, and the quality of the land (humus content in soils).

An important degree of dependency and grouping of the regions of Ukraine between 1990 and 2019 was discovered using the statistical processing data method of the researched indicators in the program Statistica 10.0. Also, we demonstrated the method of mathematical and computer modelling for the prediction of humus content change in the soils of Ukraine.

The geoinformation-analytical system of organic agriculture incorporates the proposed method of humus balance calculation as an e-calculator module. The e-humus balance calculator allows the user to independently set the order of crops to be grown in rotation and the amount of organic fertilizer (biohumus) to be applied. As a result, the user can receive potential variations of the total humus content in the soil for various volumes of organic fertilizer application (biohumus) siderates.

It will be possible to develop effective ways to increase soil fertility and lessen the influence of harmful anthropogenic elements on the quality parameters of agricultural land with more research into the regulatory effects of a balanced natural economic system.

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