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*Oksana Butrym¹, Dmytro Zaruba¹, Tetiana Yehorova²,
Liudmyla Hranovska², Oleksander Shablia²*

¹State Ecological Academy of Postgraduate Education and Management

*²Institute of Climate Smart Agriculture
of the National Academy of Agrarian Sciences of Ukraine
Ukraine*

THE ROLE OF FISCAL INSTRUMENTS IN THE IMPLEMENTATION OF LOW-CARBON AGRICULTURE

Purpose. *The study purpose is to determine the aspects for improving the fiscal toolkit as an economic lever for regulating agricultural land use with the optimized approach to the selection of areas of introduction of the low-carbon development for the formation of organizational and economic management conditions towards the ensuring of restoration and preservation of agricultural resource potential.*

Methodology / approach. *In this work, we used the following research methods: monographic, statistical analysis, graphic, correlation and regression analysis. The national and international documents of legal framework for regulating the processes of agricultural land use, materials of the State Statistics Service of Ukraine were used.*

Results. *Based on the ecological and economic efficiency analysis of agricultural land use, the priority of obtaining profits in contrast to the problems of the restoration and preservation of the agricultural resource potential was demonstrated, thanks to which Ukraine took the lead in many commodity crops export. The soil fertility decline is a reason of formed threat to agroecological and food security. Based on the assessment of the nitrogen balance flows, the amount of removal of nutrients from the soil cover was estimated.*

Originality / scientific novelty. *The expediency of using an improved tax instrument for land use as an economic lever for the formation of organizational and economic conditions of management with a focus on the introduction of the principles of the green economy is substantiated. This improvement consists in the correction factor proposed for the first time to the calculated volumes of tax collections. This coefficient allows taking into account the characteristics of the land use effectiveness in combination with the coefficients of carbon stock changes of the internationally recognized methodology UN Intergovernmental Panel on Climate Change (IPCC). Based on the improvement of the target agroecological zoning approach (on the example of the Odesa region), an approach to establishing the priority of land plots from the point of view of the perspective of introducing low-carbon land use is proposed.*

Practical value / implications. *The proposed approach opens the possibility to optimize efforts to introduce low-carbon land use and therefore to restore and preserve agro-resource potential. The national crop production competitiveness is ensured by this. Therefore, this approach can be taken as a basis for the introduction of the latest green economy tools for the agricultural land use sector at the level of territorial communities.*

Key words: *agricultural resource potential, reservoir of mineral soils on agricultural lands, nitrogen balance flows, balanced land use, low-carbon crop production development.*

Introduction and review of literature. Raw material-oriented management under the conditions of increasing environmental demands of society hinders economic growth and makes Ukraine's integration into international groups impossible. It is urgent to introduce a system of restrictions on access to the internal EU product markets produced without complying with the proper requirements for the use of natural resource potential. The first step in establishing these barriers is the introduction of a mechanism for adjusting carbon limit, which concerns the crop sector, so far, only in the part of growing raw materials for the production of biofuels. However, according to European legislative initiatives, Ukraine has to fulfill a number of other requirements of an ecological and economic nature on the way to its European integration aspirations. With regard to the Land Use, Land-Use Change and Forestry Sector (LULUCF), updated rules have been formed according to which the EU countries must ensure the balance of recorded greenhouse gas emissions by 2030 by absorbing them from the atmosphere for 310 million tons of CO₂-e [1]. It is assumed that in the period until 2030, the climate-neutral food production will be achieved and among other positive results, degraded agricultural lands will also be restored.

The creation of organizational and economic management conditions under which excessive use of agro-resource potential loses its economic attractiveness will contribute to the compliance achieving of the national crop production with the European requirements of balanced nature management. The absence of such conditions contributed to the increase, according to the State Statistics Service of Ukraine, of the volume of gross crop production over the past ten years almost twice (from UAH 329.6 billion in 2010 to UAH 580.3 billion in 2021 in the 2016 price calculation), and from 2018, the volume of crop production per 100 hectares of agricultural land increased by more than 10% (from UAH 1.3 to 1.5 million) [2]. Instead, the creation of such conditions will ensure the economic interest of land users (land owners) in achieving of an acceptable agroecological security level. A tax instrument using in this context, as a key in the fiscal levers system, opens the way to the formation of the dependence of increasing the level of profitability of commodity crop production, along with other factors, on the soil cover of agricultural land quality, which was formed because of the agro-technological cycle. The soil quality largely depends on the nutrients return that removed with the harvest.

The work evaluates the balance nitrogen flows in the zonal dimension that allows ranking the territories according to the level of nutrient loss with the harvest. The proposed application of targeted agro-landscape zoning on the example of the Odesa region opens up the opportunity to determine the most promising areas for the low-carbon land use launching, under the conditions of which a permanent carbon balance is ensured in the mineral soil pool of agricultural lands [3, p. 18]. The conducted assessment characterizes the agro-landscape potential for the low-carbon land use launching which can be taken as the basis of further elaborations for introducing a domestic (voluntary) carbon market for agricultural land use sector and the development of a carbon footprint assessment system. This will ensure the export

competitiveness of national commodity plant producers and can also be used as a basis for developing plans to ensure an acceptable level of agroecological and food security for the territorial communities and regions.

The problems of ensuring balanced land use, reducing anthropogenic impact on agricultural resource potential are the subject of research by a wide range of both domestic and foreign researches and scientific schools. In particular, I. Bystryakov & D. Klynovyi [4], B. Burkinsky & V. Goriachuk [5], S. Boychenko et al. [6] and others, studied the substantiation of the ecological security concept, aspects of achieving balanced land use, approaches and methods of overcoming risks and threats, assessments of their level. L. Hranovska et al. [7], B. Danylyshyn [8], L. Novakovskyi et al. [9], D. Dobriak et al. [10], A. Martyn et al. [11] and others studied the development of the main theoretical and methodological principles of balanced nature management, environmental protection, systematization of approaches to practical improvement of the environmental protection system. Yu. Lupenko et al. [12], S. Baliuk et al. [13], and others [14] made a significant contribution to the development of the economic foundations of the balanced use of agricultural lands.

M. Bogira [15], Y. Jiang [16] and others studied aspects of market formation and regulation for the agricultural land use sector. The research of M. Berezhnytska et al. [17], O. Butrym et al. [18], A. Kitury [19] and others is devoted to the study of the implementation of the carbon market and highlighting the role of the state in regulating greenhouse gas emissions.

The issue of the dynamics of greenhouse gas emissions regulating by economic methods has received wide attention throughout the world. For example, the work of J.-E. Tchaphet-Tchouto [20] is devoted to the specifics of the impact of environmental taxes on economic development, where the ambiguity of the resulting impact is shown for countries with different economic development, because the increase in environmental taxes creates incentives for economic development, for low-income countries– it is the additional financial burden. M. Frey [21] tried to determine the dependence between the size of the tax rate on carbon emissions and the dynamics of greenhouse gas emissions specifically for Ukraine, which demonstrated the possibility of ensuring a proportional increasing in GDP and increase in the tax obligations of producers.

It should be noted separately the works of A. Kucher, whose scientific output is devoted to the analysis of the relationship between the organic component of the soil with the economic efficiency of the crop production entities [22–24], their competitiveness [25; 26] and the search for ways the sustainable agriculture development ensure on this basis [27–29]. The study of the problems of improving the system of environmental taxation of carbon dioxide emissions, which was carried out by M. Ilchuk et al. [30] deserves attention.

These scientific developments are forming the theoretical and methodological basis for further research in the field of development of economic thought in the context of restoration and preservation of natural resource potential and agricultural

resources in particular. The achievements of previous studies are have the continuations in the substantiation of problems and the theory and practice aspects of implementing of the green transition principles, ensuring balanced land use, low-carbon development of crop production as a factor in preserving the agricultural resource potential and the developing rural areas and regions.

There are reasons to assume that the implementation of fiscal levers creates an opportunity to create special organizational and economic management conditions, under which ensuring the balanced use of agricultural land with a focus on achieving climate neutrality becomes economically attractive and ensures increased capitalization of agricultural resource potential.

The purpose of the article. The study purpose is to determine the aspects for improving the fiscal toolkit as an economic lever for regulating agricultural land use with the optimized approach to the selection of areas of introduction of the low-carbon development for the formation of organizational and economic management conditions towards the ensuring of restoration and preservation of agricultural resource potential.

Achieving the specified goal is ensured by the following tasks:

(i) to carry out on a systematic basis an ecological and economic efficiency assessment of the commodity crop production in the zonal dimension of Ukraine;

(ii) on the basis of the identified cause-and-effect relationships, propose an approach to optimize the functioning of the tax instrument as a lever for ensuring the balanced use of agricultural land, taking into account the problems of climate change;

(iii) to propose an approach to optimize the introduction of low-carbon land use using targeted agro-landscape zoning on the example of Odesa region, as the most representative in terms of agro-climatic aspect among other regions of the steppe farming zone, for which the highest volumes of carbon stock reduction in the mineral agricultural soil pool are observed.

In this work, we used the following research methods:

- monographic – for the promising aspects identification of land use management processes improving based on the involvement of fiscal levers;

- statistical analysis – for the current land use state assess and ecological and economic features of ensuring its low-carbon development;

- graphic – for the visualization of analytical and statistical materials and obtained results;

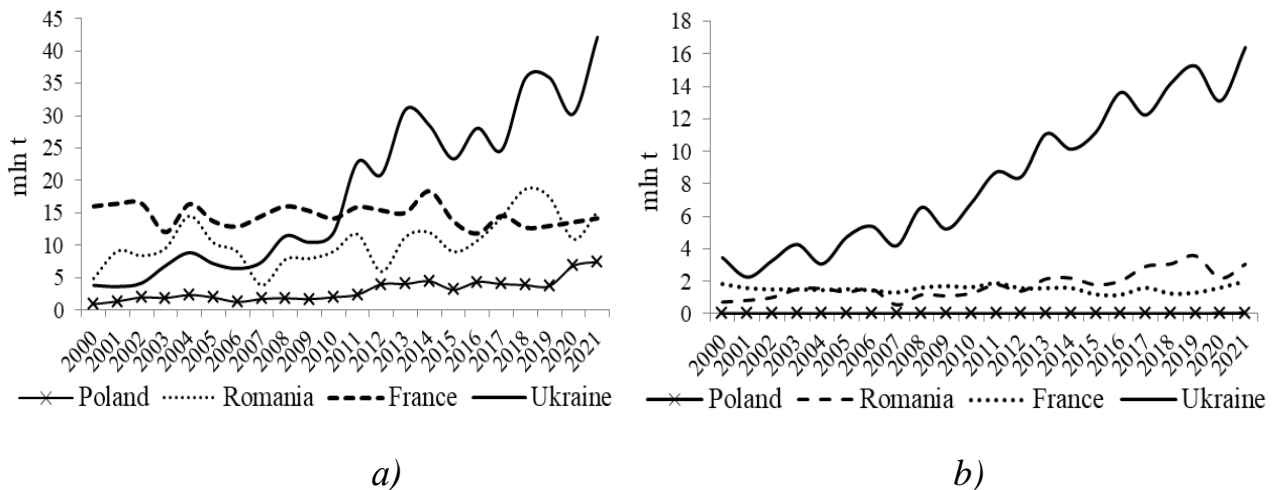
- correlation and regression analysis – for the establish and measure the degree of dependence and mutual influences of an agro-resource nature on the effectiveness and features of the application of financial and economic tools of the introduction of low-carbon agricultural land use.

Results and discussion. *Ecological and economic efficiency assessment of commodity crop production in the zonal dimension of Ukraine.* Today's realities, taking into account the requirements of the international community to regulate the climate change process, increase the urgency of introducing a low-carbon development strategy of all economy sectors. The production volume increase occurs

due to the depletion of natural resource potential, and taking into account the cost of resources involved in the production process is insufficient, which threatens environmental safety. One of the reasons is that agro-technological cycles have significant external effects, which are not fully included in the market prices formation for commodity crop production. The first step to correcting some of these external effects is their transparent assessment, based on which a total accounting of costs can already be carried out [31]. Thus, the need to reform the organizational and economic relations between subjects of economic activity in the process of nature use for the activation of low-carbon development has become ripe. Researchers not only in Ukraine [32] consider a similar range of questions. For this, the international community, and primarily the European Union, is making active efforts to steadily reduce greenhouse gas emissions with the gradual achievement of net-zero volumes. The ambition level of such obligations requires not only the intensification of the energy-saving measures improving and a number of other actions at the macroeconomic level, but also the strengthening of the influence on the volume of greenhouse gas (GHG) absorption increasing. In this regard, in July 2021, the European Commission published a package of legislative initiatives “Fit for 55” [32], which include the LULUCF Regulation [33]. This document announces the EU’s goal of increasing the amount of GHG absorption under proper monitoring. The agricultural land use sector plays an important role in this context, as the mineral soils pool has the ability to increase carbon stocks through the accumulation of humus. It is assumed that in the period from 2026 to 2030, the EU member states will fulfill the assigned distributed obligations of the achieving the joint total stated amount of absorption, which will ensure climate-neutral food production and, along with other positive results, will facilitate the restoration of degraded agricultural land.

The key goal of these reforms is to create conditions under which the rate and volume of added value growth will directly take into account the value of environmental services, which is created by the components and characteristics of the environment, and to have developed levers for taking into account the effects of the anthropogenic load levels created by a certain of economic activity types. A resource-depleting way of conducting agriculture due to excessive use of agricultural resource potential is unacceptable not only from the point of view of ecological expediency, but also economically unprofitable. This can be explained by the fact that the restoration of the acceptable agroecological state of the territories requires much larger capital investments than the ecologically balanced organization of crop production. With regard to Ukraine the situation is taking on threatening contours, since the national production of food raw materials in a number of positions was the first among the countries of the European Union (Figure 1).

The location of the branches of graphs of Ukraine above the other countries demonstrates the primacy of national producers of such crops as sunflower and corn for grain, which confirms the potential of Ukraine as one of the largest producers of food. Odesa region ranks ninth in Ukraine in terms of the commodity plant production (5.2 % is produced).



**Figure 1. Dynamics of production volumes in Ukraine and EU countries:
a) corn and b) sunflower**

Source: created by the authors based on Eurostat data.

High profits volume of agricultural producers is directly related to this, which is a factor of unbalanced land use and is proven by comparing the agricultural land areas dynamics and their constituent components with the areas of various crops production, which are shown in Figure 2. Despite the constant reduction of the total agricultural land area, the arable land area as a its component has steadily grown over the last decade (see in the Figure 2a) due to the area of ecologically stabilizing lands which are the perennial crops, fallows, meadows, pastures areas (see in the Figure 2b).

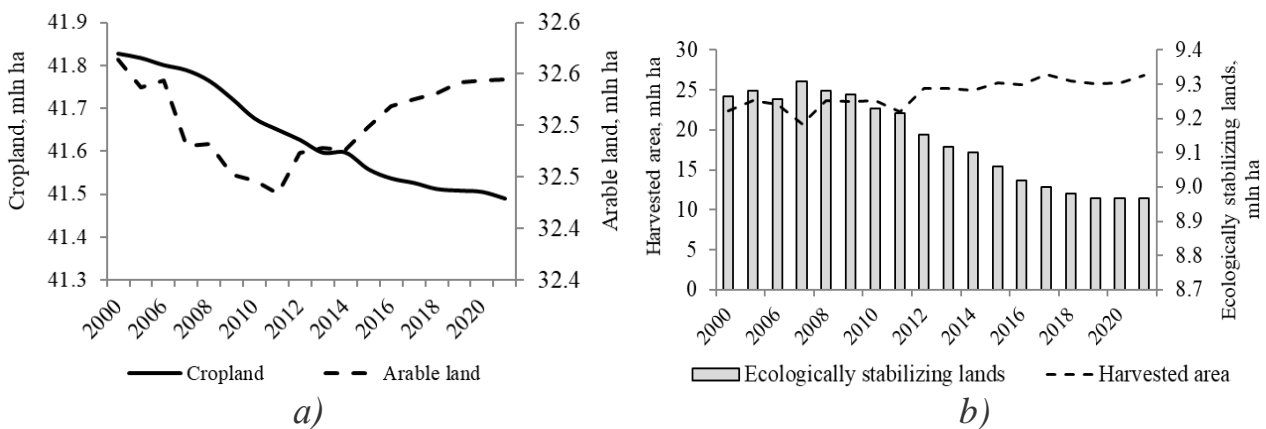


Figure 2. Area dynamics: a) agricultural land and arable land; b) fallows and perennial plantations and meadows and pastures, thousand ha

Source: created by the authors based on State Statistics Service of Ukraine.

Unbalanced land use in Ukraine is aggravated by the expansion area rate of highly profitable crops, for example, the area of winter wheat, corn for grain, and sunflower has more than doubled since 2000 (in common from more than 9 million ha in 2000 to more than 19 million hectares in 2021). Similar trends are typical for Odesa region. At the same time, the sown area of grass crops decreased by almost four times from 3.9 million hectares to 1.1 million hectares during the corresponding period, which indicates a reduction in the livestock population, and therefore, the

amount of manure applied. This leads to an increase for fertilizers and, most of all, nitrogen fertilizers, which is shown in Figure 3. Described situation is a main reason of a decreasing in the indicator of the soil environment acid-alkaline balance, i.e., about its acidification.

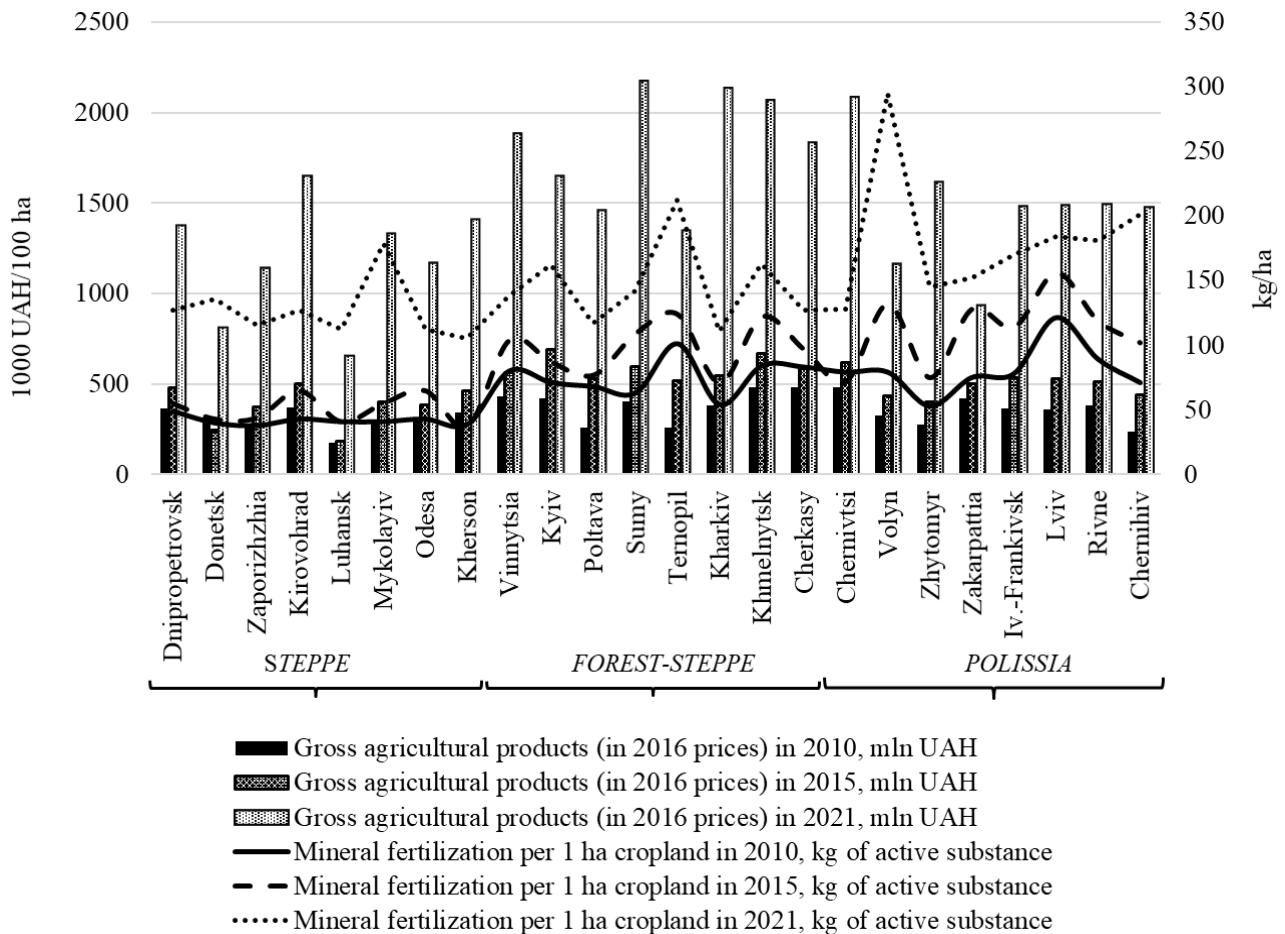


Figure 3. Amounts of applied mineral fertilizers, kg per 1 ha of sown area and volumes of gross crop production in all agricultural holdings per 100 hectares of agricultural land in zonal measurement in 2016 prices

Source: created by the authors based on State Statistics Service of Ukraine.

There has been a tendency to increase the nitrogen fertilizers share in the total amount applied to the soil since 2009 (more than 70 % instead of the optimal 40–42 %). In 2021, sources of mineral nitrogen prevailed 28 times over the nitrogen of organic origin (for the Odesa region this ratio was 79.8/1), thanks to which high profitability indicators of crop production are maintained. The clear tendency exists of the fertilizers application increasing in the regions of Polissia zone, which is explained by the lower level of natural soil fertility compared to the rest of the regions. At the same time, the highest level of crop production profitability in the measure of thousand hryvnias from 100 hectares of agricultural land in 2016 prices are characteristic of the forest-steppe zone of Ukraine due to more fertile soil in a complex with optimal moisture characteristics, which is confirmed by the “wave-like” bars growth in the middle part of the graph for all years.

It should be noted the constant increase in the anthropogenic loading level on

the agroecosystem which is confirmed by the location of the information both of the parameters for each subsequent year of the analysis upper the schedule of the previous year. Unbalanced fertilizers using with a predominance of the mineral nitrogen component contributes to the disruption of the nutrients balances, the deterioration of their circulation together with the agrochemical properties of the soil, and ultimately leads to the loss of its fertility and the agricultural resource potential reduction. Despite the increase in the volume of mineral nitrogen fertilizer application almost eight times (from 2.2 million tons in 2020 to 17.7 million tons in 2021) in Ukraine and 3.5 times (from 287.2 thousand tons in 1998 to 1,017.0 thousand tons in 2021) in the Odesa region, in most cases, it is impossible to compensate for the amount of removed nutrients. This statement is proven by calculations, for example, in 2021, 1.8 million tons of nitrogen was removed by the useful part of all agricultural harvested crops in Ukraine, and one and a half times more with root part and by-products of plants (Table 1).

Table 1

**Balanced “output-input” nitrogen flows (N) during crop cultivation
in Odesa region, tons**

The name of flow	1995	2000	2005	2010	2015	2021
<i>Nitrogen removal from soil by harvested crops</i>						
Nitrogen removal by useful part of harvested crops	60 623.9	66 847.3	78 565.2	80 703.7	102 961.1	141 681.1
Nitrogen removal by sub-product part of harvested crops	60 184.3	60 633.2	102 266.1	82 883.9	114 941.9	128 250.8
<i>Total</i>	120 808.2	127 480.5	180 831.3	163 587.7	217 903.0	269 931.9
Nitrogen removal, kg N/ha harvested area	76.5	92.1	79.9	92.4	119.4	146.0
<i>Inflows of nitrogen to the soil environment</i>						
Consumed by plants from harvested crop residuals	41 504.9	37 341.1	62 584.0	52 290.6	70 617.8	76 935.5
Consumed by plants from nitrogen mineral fertilizations	8 393.2	7 015.0	11 037.5	13 503.5	17 783.1	28 449.3
Consumed by plants from manure	37 911.1	23 374.4	17 934.3	15 328.2	7 822.0	14 132.2
Entered into the hummus from harvested crop residues and by-products	23 843.2	23 357.8	32 655.9	31 709.3	37 442.0	37 030.3
Entered into the hummus from manure	393.0	244.9	184.1	155.8	90.0	60.6
Symbiotic nitrogen fixation	1 748.8	1 739.0	1 776.0	1 452.0	1 140.8	638.4
Not symbiotic nitrogen fixation	8 688.1	7 614.3	12 455.0	9 734.3	10 041.4	10 171.7
<i>Total</i>	122 482.4	100 686.6	138 626.8	124 173.7	144 937.0	167 417.9
<i>Balance</i>	1674.2	-26 793.9	-42 204.5	-39 413.9	-72 966.0	-102514.0
<i>Nitrogen balance, kg N/ha harvested area</i>	1.1	-19.4	-18.6	-22.3	-40.0	-55.4
<i>The ratio of the amount of nitrogen removal to its intake</i>	0.99	1.27	1.30	1.32	1.50	1.61

Source: created by the authors based on State Statistics Service of Ukraine and methodology [3, pp. 140–152].

The quantities of nitrogen removed from the soil layer of agricultural land during the research period increased by 2 times (from 127.5 thousand tons to 270.0 thousand tons) in absolute terms. If we compare this characteristic in relation per to a unit of area, the observed increasing is in a slightly smaller proportion – 1.6 times (from 92.1 kg N/ha in 2000 to 146.0 kg N/ha of the harvested area), which is explained by different yield indicators for different crops. It was possible to compensate this nitrogen removal by only 70 % through the nutrients entrance with fertilizers (mineral and manure), with harvested crop residues, roots, by-products, because of symbiotic and non-symbiotic nitrogen fixation. This ratio is not stable by natural zones that evidenced by the results of the carbon stock change assessment for mineral soil pool (Figure 4): a) illustrates the situation for Ukraine as a whole and in the zonal dimension, in particular in the steppe zone; b) in Odesa region.

The highest degree of stability according humus stock changes and therefore carbon belongs to the situation in Polissia, as evidenced by the greatest approximation of the graph to the OX axis. An increase in the intensity of use of agro-resource potential is observed for the Forest Steppe. Although the branch of the graph “rises” the highest, relative to the graphs of the rest of the situations with the carbon stock change in mineral soils pool by natural zones, there is also a greater reduction of these stocks, therefore these lead to higher CO₂ emissions from the agricultural land using. The largest volumes of CO₂ emissions from the land use in the crop production are characteristic of the steppe zones of Ukraine, which is reflected in the overall dynamics of the carbon stock decreasing in the soil pool of agricultural lands. At the same time, the graph of the dynamics of lease payments for the use of agricultural land shows a rapid growth during the studied period – almost nine times (from more than UAH 5 billion in 2010 to more than UAH 46 billion in 2021). This distribution is explained by the intensity of the anthropogenic load on the agroecosystem. The results of monitoring observations on the agroecological state in Ukraine [34, p. 7] showed that during the last two decades there was a reduction to a minimum of comprehensive soil improving measures and some works were not carried out at all. This leads to a steady trend of soil quality deterioration, which is reflected in the dynamics of indicators of the amount of lease payments for the use of agricultural land, while simultaneously taking into account information on the carbon stock change dynamics in the mineral soils pool of agricultural land. Comparison the GHG emissions dynamics in a complex with the economic dynamics indicators of land use is the embodiment of the results of anthropogenic load on the agroecosystem and an indicator of the agroecological security level of the region.

As an economic component of this ecological and economic aspect of the analysis, it is proposed to consider the dynamics of lease (rental) payments. This choice is justified by the fact that the most common legal form of agricultural land use in Ukraine during of the last decade is economy instrument of lease. It is thanks to this method of land use that such forms of management as agricultural holdings received the greatest activation of development. This form of land use organization has its positive and negative sides. Thanks to the lease mechanism, many landowners

have the opportunity for a moderate rent, the amount of which is subject to statistical accounting, to ensure the use of the plots (shares) granted to them by the state for their main purpose – agricultural.

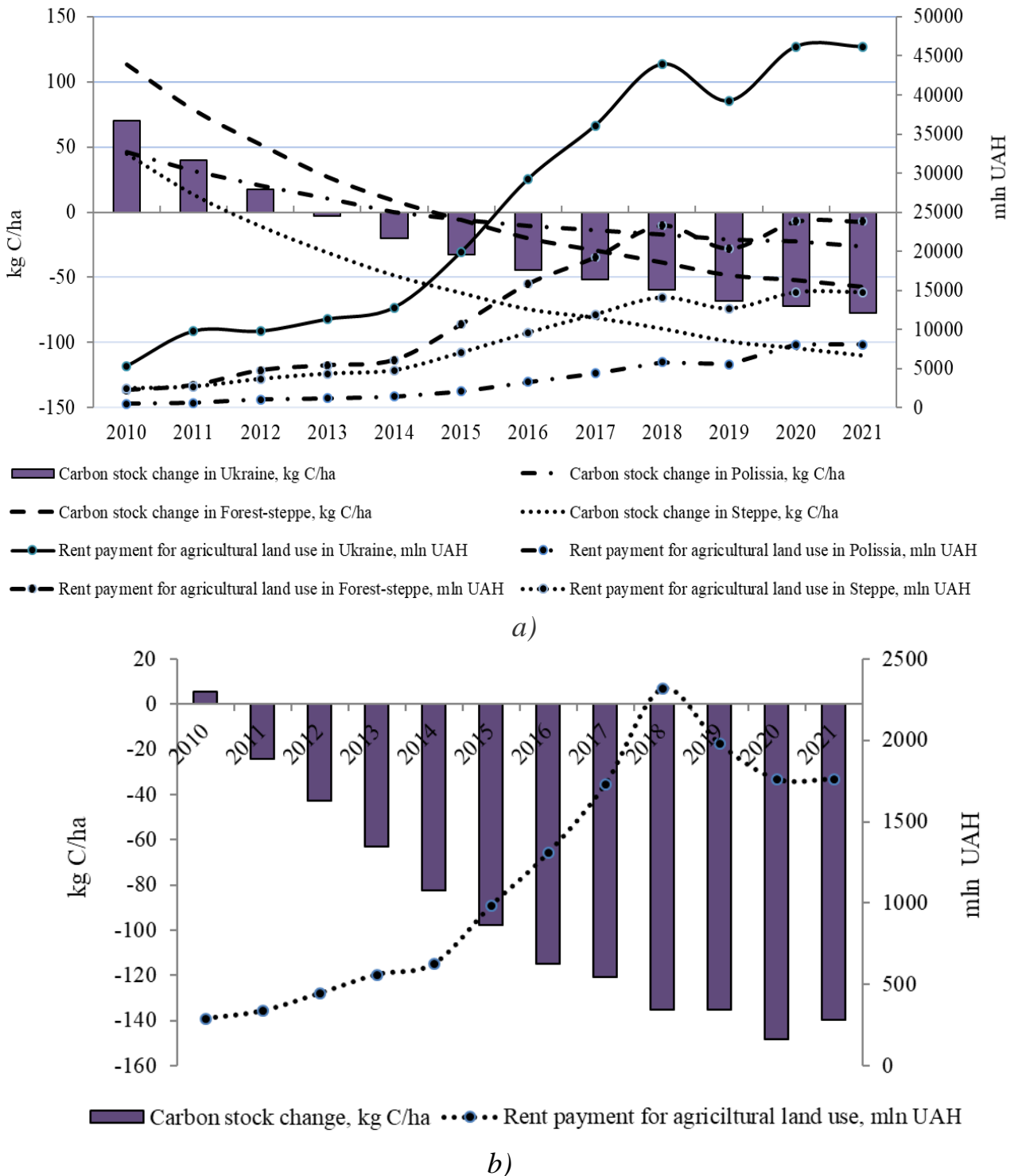


Figure 4. Carbon stock change in mineral soil pool of agricultural land, kg C/ha and rent payment for agricultural land use, mln UAH: a) per nature zones of Ukraine; b) in Odessa region

Source: created by the authors based on State Statistics Service of Ukraine and methodology [3, pp. 140–152].

Nevertheless, the land, which according to Article 13 of the Constitution of Ukraine “is the property of the Ukrainian people”, is alienated from the landowners. That is, citizens of Ukraine have transferred the rights to use agricultural lands to other economic entities in accordance with lease agreements. Before February 24, 2022, any natural or legal person had the right to obtain an agricultural plot for rent by entering into appropriate contract with its owner/manager. This could be done through auctions or direct contracts (at the owner’s discretion). Such a contract was entering into force after the fact of its state registration.

The consequence of the described situation was that, according to information from the Latifundist.com website: “Today, more than 10 foreign agricultural holdings from the Top 100 latifundist rating are operating in Ukraine. Now 3–4 million hectares are under their control. The largest foreign agricultural holdings in the country are the American “Agroprosperis” (has the land bank of 300,000 hectares) and “Continental Farmers Group” (195,000 hectares)” [35]. At the same time, according that source, the general land bank is at the disposal of all agricultural holdings operating in Ukraine with an area of agricultural land of 10,000 hectares or more as of 2023, taking into account the territories that fell under the zone of active hostilities in the east of Ukraine was almost 6 million hectares. This amounts to 14.3 % of the agricultural land area and 18 % of cropland (the rate of spread of erosion soil processes cover of arable lands of Ukraine is comparable to the indicated values). Since the tenant (land-user) is not the owner of the land that is used, this fact does not contribute to the formation of a thrifty attitude towards the land.

Let’s consider the ecological and economic efficiency of agricultural land use in the zonal dimension. The variation of the change in the carbon stock in the pool of mineral agricultural soils, which is determined by the dynamics of gross crop production, will be estimated using the coefficient of determination (R^2), Figure 5. The dependence degree between these parameters is also determined by pair coefficients correlation, which is: for Ukraine as a whole – -0.91; for Polissia – -0.87; for Forest-Steppe – -0.92 and for Steppe – -0.919. For all the above cases of dependence, the relationship is high degree inverse. That is, with the growth of payments for the lease of agricultural land, which according to statistical data increased almost 9 times over the ten-year period of the study (from UAH 5,295.5 million in 2010 to UAH 46,192.9 million in 2021), at the same time, there is a decrease in carbon stocks in the pool of agricultural soils, which are used for commodity crop production.

Taking into account the statistical parameters of the regression (confidence interval for the line slope on the graph), it is possible to determine the quantitative dependence between the values of the indicators, in particular: there are grounds with a probability of 85 % to claim that the increase in anthropogenic load on the national agricultural land, which is expressed in the increase in the yield of crops, for example, wheat, by 0.1 t/ha will lead to an increase in GHG emissions per hectare of arable land on average up to ≈ 0.25 – 0.3 kg of carbon (or 0.9–1.1 kg of CO_2) under the conditions of existing agro-technological land cultivation practices. The

assessment was carried out under the condition of using traditional agricultural practices and agro-technological methods without taking into account the amount of GHG emissions from fuel consumption by agricultural machinery.

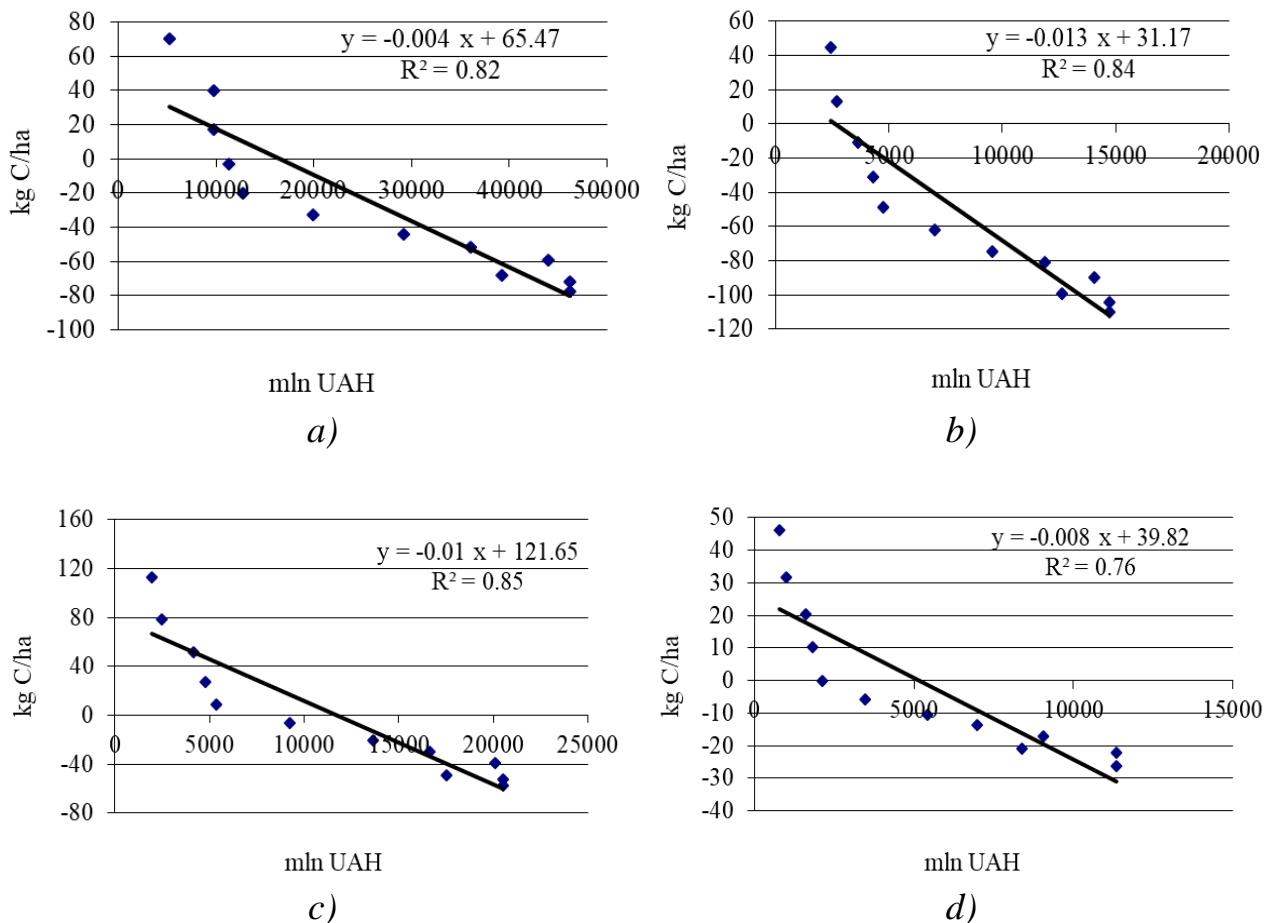


Figure 5. Correlation field and the correlation dependence graph of the dynamics of carbon stock change in mineral agricultural soils pool and the amount of lease payments for the use of these land in (a) Ukraine and in the zonal dimension: (b) Steppe, (c) Forest Steppe, (d) Polissia during 2010–2021

Source: created by the authors.

An approach to optimizing the functioning of the tax instrument as a lever for an ensuring the balanced land use, taking into account the problems of climate change. The indicated results of the conducted assessment are confirmation of unbalanced land use in Ukraine, which leads to GHG emissions, threatens the acceptable level of agroecological, and ultimately food security, prevents the balanced use of agricultural lands of Ukraine. In addition, these research results reveal the potential of restoring and preserving the agricultural land fertility and provide an opportunity to predict the carbon stock change dynamics, subject of the ecological and economic mechanism adjustment. The fiscal instrumental group is a key component of this mechanism, which aimed to improve of organizational and economic management conditions with the orientation towards recovery and preservation of agricultural resource potential. In the case of deterioration of the quality state, which can be seen as the decreasing of humus stock (and, therefore,

carbon) in the agricultural soils, the financial burden on land users should be increased. Alleviation of economic burdens, embodied by the tax on the use of agricultural land plots, can be achieved after receiving confirmation of the carbon stock increasing in the mineral soil pool of agricultural lands, which are involved in the commodity production of crop.

The effective economic levers on this path are the fiscal direction tools (taxes, subsidies, budget expenditure system formation). Since land is the basis for locating economic sectors and activity types, as well as a means of production, a subject of labor, a tool of production, the land use sector influences on all economy sectors. From this point of view, in our opinion, the method of calculating the land tax to optimize the balance of the “profits – agroecological security” system requires additional attention.

The researching working hypothesis regarding the tax instrument using as an effective lever of ecological and economic policy to solve the problems of restoration and preservation of agricultural resource potential is that the increase in humus reserves, and therefore the reduction of GHG emissions from agricultural land use, should be in the proportionally relationships to the amount of tax assessments for the use of these lands. “Using the tools of fiscal policy, the state creates conditions under which it becomes profitable for economic entities to take into account the interests of the state in the process of their activity” [36]. That is, the measure of the effectiveness of the application of the land tax can be considered the formation of organizational and economic conditions of management, under which the profit of agricultural commodity producers becomes dependent not only on the volume and quality of marketable crop production, but also on the quality of the agricultural soil fund formed as a result of their cultivation. The land tax should create conditions for economic stimulation to restore and preserve agricultural resource potential.

World practice has accumulated a wide enough experience in the application of fiscal and, including, tax instruments to regulate the volume of GHG emissions, however, the functioning of financial and economic instruments of a similar direction in Ukraine requires, as shown by business practice, optimization. The calculation of land tax payments is based on the instrument of normative monetary valuation of agricultural lands [37], which does not ensure the creation of economic incentives for the preservation of agricultural resource potential. Instead, this approach introduces an economically uniform environment that makes it almost impossible to take into account the permanent impact of agro-technological characteristics of land use. The existing approach does not have a sufficient flexibility for the formation of organizational and economic conditions of management, which would ensure the implementation restricting incentives of the excessive exploitation of agricultural land resourcing potential. Completion of this task is seems be possible by applying correction coefficients. The principle of taking into account the influence of the anthropogenic loading at the land by agricultural using of it use is proposed in the guidelines of the IPCC [38] through the so-called correction coefficients of changes in relative carbon stocks (Table 2):

Table 2

Relative coefficients of changes in carbon stocks for various characteristics of agricultural land use management (acceptable for the agroclimatic conditions of Odesa region)

Type of coefficient	Meaning	IPCC, 2006	Description
Land use (F_{LU})	Long-term land cultivation	0.80	Represents area that has been under tillage for >20 years, predominantly annual crops
	Perennial / Tree Crop	1.00	Long-term perennial tree crops such as fruit and nut trees
	Set aside (< 20 years)	0.93	Represents temporary removed annual cropland (e.g., conservation reserves) or other unused cropland that has been restored with perennial grasses
Tillage (F_{MG})	Full	1.00	Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (e.g., <30%) of the surface is covered by residues
	Reduced	1.02	Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Normally leaves surface with >30% coverage by residues at planting
	No-till	1.01	Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control
Input (F_i)	Low	0.95	Low residue return occurs when there is due to removal of residues (via collection or burning), frequent bare fallowing, production of crops yielding low residues (e.g., vegetables, tobacco, cotton), no mineral fertilization or N fixing crops
	Medium	1.00	Representative for annual cropping with cereals where all crop residues are returned to the field. If residues are removed then supplemental organic matter (e.g., manure) is added. Also requires mineral fertilization or N-fixing crop in rotation
	High without manure	1.04	Represents significantly greater crop residue inputs over medium C input cropping systems due to additional practices, such as production of high residue yielding crops, use of green manures, cover crops, improved vegetated fallows, irrigation, frequent use of perennial grasses in annual crop rotations, but without manure applied (see row below)
	High – with manure	1.37	Represents significantly higher C input over medium C input cropping systems due to an additional practice of regular addition of animal manure

Source: [38, pp. 5.20–5.21].

- the type of land using (F_{LU}) – considers the permanent or temporary soil cultivation; or under perennial tree or berry plantations, rice checks, or conversion of plots with a reduced fertility level under erosion processes to forest plots or onion

pasture lands, or wetland complexes. This group of factors also includes the characteristics of crop rotation accounting;

- the type of land management (F_{MG}) – the cultivation shape, which takes into account the intensity and depth of land cultivation. This coefficient of mixed influence, which allows taking into account the measure of anthropogenic load from the characteristics of the intensity of nutrient consumption by plants of various agricultural crops;

- the method of using fertilizers (F_i) – the intensity of use of soil resources, which allows taking into account the impact of different volumes and types of application of fertilizer materials, manure or other means.

The indicated specified coefficients system was developed for the preparation of the inventories of emissions from sources and absorption by sinks of GHG for the LULUCF sector according to an international generally recognized approach. The proposed approach will make it possible to take into account the financial and economic costs of land users with a higher degree of transparency and objectivity and opens the way to the formation of organizational and economic management conditions, under which excessive exploitation of natural resource potential loses economic attractiveness. Instead, the implementation of a system of land protection measures and agro-technological methods, which are focused on the restoration and preservation of agro-resource potential, should reduce the tax burden on business subjects of commodity crop production. Therefore, taking into account the results of calculations of nitrogen balance flows by the amount of nitrogen removed with harvested agricultural crops and its return (Table 1) to the amount of tax assessments, it is proposed to apply a correction factor for taking into account the removal of nutrients according to the formula:

$$T_d = \text{if} \left(\left(\frac{n_{N_{2O}removal}}{n_{N_{2O}return}} \leq 1 \right) : T \div d_i ; (T \times d_i) \right), \quad (1)$$

where T_d – the amount of tax assessments with the economic activity impact on the land state based on the previous year results, UAH;

$n_{N_{2O}removal}$ – nitrogen removal volumes with harvested crop per unit area, kg N/ha, Table 1;

$n_{N_{2O}return}$ – nitrogen returned volumes to the soil surface from all sources, Table 1;

T – amount of tax assessments, UAH;

d_i – correction factor taking into account the sublimated influence of land use characteristics in crop production under the soil and climatic conditions of Ukraine.

The calculation is carried out using the selection operator according to the criterion of the ratio between the volumes of nitrogen removal to the volumes of its compensation in the agricultural mineral soils pool: if the ratio is less than one, so the compensation prevails over the removal with the harvest. The adjustment degree of the tax assessments amount in formula 1 is proposed to determine through the

correction coefficient (d_i) based on the adjustment factors of the UN IPCC methodology according to the equation:

$$d_i = \frac{n_{N^{removal}}}{n_{N^{return}}} \times (F_{LU} + F_{MG} + F_I), \quad (2)$$

where F_{LU} – takes into account the characteristics of the way the land plot is used for agricultural purposes (arable land or perennial plantations, or meadow and pasture land, fallow land);

F_{MG} – considers the characteristics of land plot cultivation;

F_I – takes into account the characteristics of fertilizer application.

For example, let's consider a hypothetical farm that may be located in the Odesa region. The most common situation regarding land use characteristics in the mid-1990s was the following: long-term arable lands with annual deep plowing are under cultivation. A useful part of the crop and straw (by-products) for the needs of animal husbandry are removed from the field, which involves the use of manure. As a hypothetical example, we can rely on the results of the calculations given in the Table 1. Therefore, the sum of the coefficients of changes in carbon reserves (Table 2) for the first case will be: $0.8 + 1.0 + 1.37 = 3.17$.

For another case, let's assume the conditions, which in the vast majority developed with the land cultivation in 2021 – old arable land with annual deep plowing is also under cultivation. At the same time, only a useful part of the crop is removed from the field with a reduced amount of organic fertilizers, but the amount of mineral fertilizers has increased. Therefore, the sum of the coefficients of changes in carbon reserves (Table 2) for the second case will be: $0.8 + 1.0 + 1.0 = 2.8$.

These values should be multiplied by the results of the ratio of the volumes of nitrogen removal to the volumes of its return to the soil cover for each of the cases, according the equation 2. For the first case, 1995: $0.99 \cdot 3.17 = 3.13$, and for 2021: $1.61 \cdot 2.8 = 4.51$. According to the proposed improvement for tax assessments (equation 1) the amount of funds that must be paid in the form of land use tax for the business entity in the first case will be reduced by more than 3 times, and in the second case – will increase by 4.51 times.

The criterion of the ratio between the amount of nitrogen removal and the amount of its compensation in the reservoir of mineral soils of agricultural land determines the extent of the farmer's resource investment in maintaining the quality of the soil cover during crop cultivation. If the ratio is less than one, the compensation prevails over the removal with the harvest which indicates about the material, technical, organizational, economic, financial and resource of the farmer efforts. That attitude towards land resources must be supported and encouraged. Therefore, when applying the coefficient in this case, the total amount of tax assessments is reduced, as well as the financial burden on the owner. The opposite situation indicates the obtaining crops due to the activation of mineralization processes of the soil humus component which does not contribute to the restoration and preservation of agro-resource potential, the preservation of an acceptable level of

agroecological safety, and potentially threatens food security in the future due to a decrease in humus reserves. This attitude towards land resources must be restrained and limited.

Targeted agro-landscape zoning application (on the example of Odesa region) to optimize efforts for low-carbon land use introduce. Thus, the proposed approach has a certain flexibility degree to take into account the local peculiarities of crop management in order to optimize the land users (land owners) efforts to ensure low-carbon land use. Incentives for achieving an acceptable level of agroecological security are formed when applying the considered approach not only in the case of land tax assessment. Also, the specified approach can create a stimulating effect through the price of the plot (in the case of applying the considered parameters to the methodology for evaluating land plots for agricultural purposes) and due to taking into account the specified approaches when developing priority programs of regions or industry programs, etc. This is the key to the formation of such farming conditions under which unbalanced land use will be economically unprofitable. But the low-carbon land use introduction requires additional efforts, resource provision and time. At the same time, the state of the soil cover and the agro-ecosystem of the region should be taken into account, which also determine the success of the low-carbon land use launching. In order to optimize costs, it is necessary to take into account territorial heterogeneity for the most promising areas determination under the implementation of such measures, which will achieve positive ecological and economic effects in the shortest possible time.

The proposed approach has a certain degree of flexibility – both to take into account the local peculiarities of crop production and the spatial heterogeneity of agricultural lands. The low-carbon development of crop production is connected both with the improvement of fiscal instruments and with the need to take into account territorial natural and anthropogenic factors of the agrosphere functioning through the use of a system of targeted agro-landscape zoning.

The relevance of targeted agro-landscape zoning is due to three main aspects:

1) introduction of general scientific principles of coherence and differentiation into the system of zoning of the agricultural sphere;

2) the final result of zoning, namely the territorial graphic model, determines the sequence of solving the given problem of agricultural production and allows improving the technologies of agricultural production by the point method, that is, in individual local areas;

3) assessments of the formation and development of the problem of introducing land use on the basis of low-carbon development relate to the assessment of various components of the agrosphere (soils, waters, rocks, natural and cultural biocenoses), while their traditional separation as independent natural and anthropogenic objects to some extent contradicts the principle of the unity of the agrosphere.

Traditionally, the features of the soil cover are considered as the main means of agricultural production, and the existing yield as an indicator of its efficiency. Until recently, the leading tool for spatial differentiation of land remains soil grading,

which is used to assess the upper arable layer of the soil according to its agrochemical parameters. However, in modern conditions of qualitative and quantitative land degradation global processes relationships in the “soil – agrocenosis” system have acquired a complex multivariate character, which requires their complex ecological analysis. If information is available, the quality of agricultural products indicators can also be taken into account.

Targeted agro-landscape zoning for forecasting the introduction of low-carbon land use was carried out by us for the territory of the Odesa region. Regional studies shown the lands of this region are distinguished by high volumes carbon stock decreasing in the mineral soil pool because of commercial crop production. The territory of Odesa region is located within three natural-agricultural zones, there are forest-steppe, steppe and arid steppe. For this reason, there is a wide variety of agro-landscape characteristics in the selected region and, accordingly, different potentials for the implementation of low-carbon land use.

The method of zoning, as well as its principles, approaches and graphic models, is based on scientific and methodological developments of the author [39–43]. It should be emphasized that an informative territorial low-carbon land use forecasting is based on the methods of agro-landscape mapping and zoning of agricultural lands with accounting the adjacent territories. The area of each agricultural landscape was determined by a complex of 8 structural and agrochemical factors of natural and anthropogenic origin. The following factors were chosen as such factors: agroclimatic balance of heat and moisture, functional land zoning, river basins and hydro chemical composition of waters, natural and anthropogenic vegetation cover, planar soils erosion, morph structures of the relief, types and grades of soils, lithology and stratigraphy of soil-forming rocks, atmospheric pollution. Spatial diversity of these factors is systematized according to 8 taxonomic categories and 25 taxa. On the territory of the region, 31 agricultural landscapes have been allocated. For the territory of each agro-landscape, a forecast target expert assessment of carbon input into the atmospheric air was performed. Such assessment is measured in points and is based on the ranking of quantitative and qualitative parameters of the corresponding taxonomic category. The expert assessment of each agricultural landscape takes into account the following parameters, respectively: Selyaninov’s hydrothermal coefficient; the level of disturbance of the natural structure of the land; intensity of evaporation from the surface of rivers; afforestation of the territory; mechanical composition of soils and their erodibility; direction of mechanical air migration processes; enrichment of soil-forming rocks with carbonate compounds; entry of natural carbohydrates into atmospheric air. The value of predictive estimates of low-carbon land use for agro-landscapes of the Odesa region varies from 11 to 19 points (Table 3, Figure 6).

Agricultural landscapes with a target expert assessment of 16–19 points have been identified as *the most favorable for low-carbon land use*. This category includes 9 agricultural landscapes. They prevail in the forest-steppe zone and are characterized by homogeneous parameters of the zone, subclass and subspecies according to

taxonomic classification. In addition to the highest hydrothermal coefficient, they are united by high soil erosion and the unpromising nature of rocks on hydrocarbons.

Table 3

Categorization of agricultural landscapes of Odesa region according to the level of forecast assessment of low-carbon land use

Natural and agricultural zone of Ukraine	Categories condition of low-carbon land use	Comprehensive expert assessment, points (in the numerator) and number of agricultural landscapes (in the denominator)
Forest Steppe	The most favorable	$\frac{16-19}{7}$
	Favorable	$\frac{15}{1}$
Steppe	The most favorable	$\frac{16}{1}$
	Favorable	$\frac{14-15}{6}$
	Unfavorable	$\frac{11-13}{5}$
Arid Steppe	The most favorable	$\frac{16}{1}$
	Favorable	$\frac{14-15}{5}$
	Unfavorable	$\frac{12-13}{5}$

Source: created by the authors.

Agricultural landscapes with *favorable conditions for low-carbon land use* meet the target comprehensive assessment of 14–15 points. This category includes 12 agricultural landscapes that mainly localized in the Steppe natural-agricultural zone with homogeneous parameters of the zone, type and subspecies. They are united by the average level of evaporation intensity from the surface of the rivers of the Black Sea and Dniester basins besides the average hydrothermal coefficient, as well as the absence of natural hydrocarbons in the rocks.

Agricultural landscapes with comprehensive expert assessment index of 11–13 points are characterized by *unfavorable conditions for low-carbon land use*. This category includes 10 agricultural landscapes of Steppe arid natural-agricultural zone, where they are united only by belonging to the zone of agro-landscapes with a low hydrothermal coefficient.

Thus, carrying out targeted agro-landscape zoning allows determining the territories with the most favorable conditions for the introduction of balanced (low-carbon) land use. The selection of plots with the most favorable conditions will ensure not only the optimization of costs, but also accelerate the receipt of additional funds from the application of the updated tax instrument based on the first proposed approach to take into account the effectiveness of land use with the IPCC coefficients of soil carbon stock change. This opens up the possibility of involving the rest of the

land under launching of low-carbon crop production and in combination with the improved fiscal levers, the conditions for achieving the acceptable cost indicators of crop production obtained in these territories are formed.

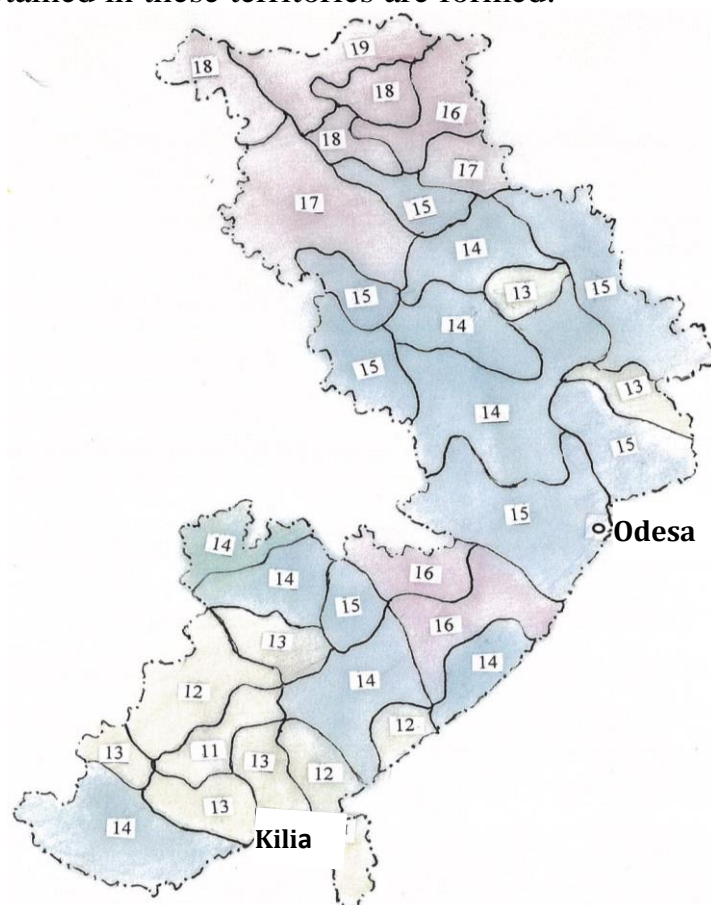


Figure 6. Schematic map of agricultural landscapes of Odesa region for the targeted forecast of the low-carbon land use launching

Conventional designations: Categories of agro-landscapes according to the prospects for the low-carbon land use launching: (purple) – the most favorable conditions (16–19 points); (blue) – favorable conditions (14–15 points); (yellow) – unfavorable conditions (11–13 points); (black line) – boundaries of agricultural landscapes; (15) – the total score of the expert assessment of low-carbon land use.

Source: created by the authors.

Discussion. In the scientific literature, when studying the taxation problems of greenhouse gas emissions from stationary sources [19] and finding ways to overcome them [20], the connection between taxes and economic development is underlined, with an emphasis on the low efficiency of such taxation in Ukraine [22; 30]. At the same time, the aspect of regulating the emissions amount that occur in natural-anthropogenic ecosystems by economic instruments is rapidly developing, which is actively being introduced in developed countries already at the level of regulatory and legislative acts [32; 33]. The peculiarity of economic activities, the object of which are the components of natural-anthropogenic ecological formations, is that absorption processes can occur as a result of economic influences (carbon stock increases in the pools of perennial living biomass or soils). When studying the

problems of ensuring sustainable (balanced) land use, which is emphasized in the above literary analysis, attention is paid to the application of economic levers [6–10]. The issues of the assessment of carbon stock change in the mineral soils pool are relevant [2; 21–24], as a starting point for the regulation of agroecological safety and a support base for the involvement of the tools of the green economy [17] and the achievement of the goals of increasing carbon absorption by the soil biocenosis and the related problems of ensuring sustainable land use [27–29].

Based on the study of the above experience, we attempted to propose an approach to improve tax regulation for the agricultural land using. The improvement consists in the formation of dependence between the volumes of tax assessments on the qualitative state characteristics of the soil cover, which is formed as a result of the commodity plant production. This approach ensures the creation of specific organizational and economic management conditions, under which exhausting land use becomes unprofitable. Therefore, incentives are being formed for the low-carbon method of crop production introduction with a focus towards increasing the volume of carbon stock in the mineral soils pool. But it should be noted that the effectiveness of proposed approach requires the formation of an information and registration infrastructure, which is based on the results of the functioning of the monitoring system not only on the qualitative parameters of the soil cover of agricultural land, but also requires the formation of an evidence base on the observance of agro-technological conditions and restrictions with the introduction of a scientifically based system of land protection measures. Fulfillment of this task requires strengthening of institutional and regulatory and legislative support.

Conclusions. The results of the study show that the existing until recently organization of the process of agricultural land use with the aim of increasing profits from commodity crop production creates an exhausting effect on the agricultural land resource potential, does not contribute to its restoration and preservation and the formation of a balanced (sustainable) way of agricultural land use.

The lack of a sufficient level of interest, responsibility, incentives and levers for encouraging business entities in decarbonization and low-carbon development of economic and industrial activity, including in the field of crop production, is a barrier and creates obstacles for the successful implementation of a system of measures in the appropriate direction. Ensuring the implementation of the strategy of low-carbon economic development requires the creation of conditions under which the rates and volumes of growth of added value will directly take into account the cost of resources, components and characteristics of the environment. To ensure the achievement of such a goal, it is necessary to develop levers for taking into account the effects of anthropogenic load levels and resources qualities, which are formed as the result of their economic use.

The degree of ensuring an acceptable food security level is determined by the level of achieving an acceptable state of agroecological security. This is directly depends on the degree of land users (landowners) interest in restoring and preserving the agricultural resource potential that are the material basis and means of

commercial production of crop production.

The leading role of the crop sector of Ukraine in commercial production of food products both for Europe and in supplying food to the countries of the world is shown. However, under the updated management conditions that are actively forming by the regulatory and legislative field of the EU, the increasing economic profits due to ecological (including agroecological) efficiency gradually becomes impossible and requires changes in the organization of the land use process.

An excessive level of nutrients removal from the soil cover of agricultural land in Ukraine due harvesting without their compensation from available sources of their return was proven. The zonal differentiation of the volumes of GHG emissions from the commodity crop production was carried out which proved the unbalanced agricultural land use that leads to the gradual loss of humus reserves from agricultural land. On average, in Ukraine, the amount of carbon emissions from agricultural land use over the last five years is 70–77 kg of carbon per hectare. The maximum volumes of emissions are observed in the zone of steppe agriculture of Ukraine, where the obtained values of emissions reached 110.1 t of C per ha in 2021; a relatively better condition is observed in the Forest Steppe (57.6 t C per ha); the lowest emissions in 2021 were observed in Polissia – 26.2 t C per ha, which demonstrates the zonal increase in anthropogenic load on agricultural landscapes.

The need to reform the organizational and economic environment for ensuring an acceptable level of agroecological and food security is substantiated. The role of the fiscal group of tools in regulating the quality indicators of the ecological state of the soil cover on agricultural lands is highlighted in this connection. By improving the tax instrument, it is possible to create an organizational and economic management environment under which exhausting land use with loss of fertility becomes economically unattractive. At the same time, ensuring an acceptable level of agroecological security leads to a reduction in the tax burden on agricultural producers that are an incentive to introduce a scientifically based system of land protection measures. Calculation of nitrogen balance flow parameters under growing commodity crop production is considered as a criterion for reducing the tax burden on land users. A condition for reducing the tax burden is the predominance of nitrogen input from fertilizer sources over the amount of its removal with the harvested crop. In addition, this is true because the achieving a value less than one requires land users to initiate sustainable (balanced) land use with certain financial, organizational and economic efforts.

An approach to agroecological zoning based on the example of agro-landscapes of the Odesa region is proposed to determine similar areas of the territory, to optimize the introduction of low-carbon use of agricultural land. Agroecological zoning in a complex with an approach to improving the fiscal instrument can be taken as a basis for the introduction of the latest tools of the green economy for the agricultural land use sector. In addition, the considered approach can be used in the development of plans for the introduction of the best agro-technological practices at the level of territorial communities and optimization of the launching low-carbon agricultural

land use in the regions.

Within the framework of one study, it is impossible to cover the solution of all problems. The scope of the considered questions is subject to the defined goal, but a number of important aspects were left out, both in terms of methodical support for the assessment of carbon stock changes and the institutional support of solving the problems of implementing low-carbon land use.

It is necessary to strengthen the methodological foundations of this process updating the coefficients of the proportional relationship between different parts of the plants of agricultural crops and the content of nitrogen and carbon in them, as well as the parameters of humification of plant residues in relation to the main soils types on which the intensification of climate change processes production takes place. The coefficients base of the calculations, which are taken as the basis of the study, the results of which are presented in our work based on the use of the technique published more than two decades ago. The requirements for updating these parameters is explained not only by and moisture regimes, but also by changes in the quality characteristics of the soil cover, which collectively determines the nutrient amount removal from agricultural land. Increasing the reliability of the estimated parameters of the processes of changing the carbon stock in the mineral soils pool will ensure higher accuracy of the application of economic levers for regulating the agroecological security state, the degree of trust in the results of calculations. In addition, issues of institutional support for the introduction of low-carbon land use require special attention.

The proposed approach is in line with the introduction of the principles of low-carbon development and the newest green economy tools, which are actively spreading both in EU countries and beyond. For Ukraine, taking into account the European integration aspirations, implementation of these tools is of extremely urgent, in addition to the fact that the introduction of low-carbon land use contributes to ensuring agroecological and food security. In order to strengthen the institutional foundations of this process, it is necessary to strengthen the regulatory framework, first of all, to update the coefficients of the proportional relationship between different parts of the plants of agricultural crops and their nitrogen content, as well as to update the parameters of the humification of plant residues under conditions of climate change, insufficient moisture in different types of soils of Ukraine.

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