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## State Decoupling Audit of Low-Carbon Agricultural Production

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**Abstract.** It is stated that the strategic benchmark for transformational changes in the economy is currently low-carbon production, the achievement of which is possible to provide with the consistent application of an arsenal of strict control measures, in particular, the introduction of state audit of low-carbon production. The effectiveness of the mechanism for ensuring the implementation of the UN Framework Convention on Climate Change has been assessed. The necessity of implementation in the domestic practice of the state audit of low-carbon production by the decoupling approach is proved. The agri-business portfolio has been formed according to the decoupling approach as one of the leaders in greenhouse gas pollution. The author's economic and mathematical models of estimation according to the decoupling approach of the impact of branches of crop and livestock production on environmental pollution are proposed. The dependence of greenhouse gas emissions on the volume of gross output of agricultural production, capital investment and current expenditures on environmental protection has been established. The results of a comparative analysis of the realism of forecasts of changes in greenhouse gas emissions according to the methodology of the National Academy of Sciences of Ukraine and the author's methodology are highlighted. A roadmap for the introduction of a state low-carbon decoupling audit of the state decoupling audit has been proposed as part of the preparation of the second nationally determined contribution to the Paris Agreement. The expediency of supplementing GRI 300 "Environmental Disclosures" with the group of indicators GRI-305.5 "Reduction of GHG emissions", formed by the decoupling approach, is substantiated.

**Keywords:** air pollution; greenhouse gas emissions; low-carbon production; state decoupling audit.

### Introduction

Activation turn of scientific research on the issue of low-carbon production is associated with the Race To Zero movement (a global UNFCCC campaign to bring together politicians and businesses, states, regions and cities, foundations and investors to ensure carbon neutral) is one of the landmark events of the beginning of the XXI century, which determines the formation of an independent scientific direction – management of low-carbon production (Lyashenko, 2015), aimed at creating a mechanism for coordination of policy and business, which in the context of climate change will ensure environmental protection, well-

being and future generations.

In this context, the issue of ensuring the effectiveness of this mechanism is extremely important, as the action of the first international mechanism of low-carbon development has proved that the Kyoto mechanisms have not had a positive impact on the situation with carbon emissions in the world. Differentiation in approaches, namely exemption from emission reduction commitments for some countries, has resulted in global emissions growth and nullified the achievements of countries that have committed to low-carbon production (Haidutsky, 2017). Consequently, the issue of enhancing the effectiveness

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of the so-called anti-carbon mechanism does not lose its relevance, but on the contrary with the exacerbation of the climate crisis is becoming increasingly important, which is what prompted further research on this issue.

## Material and Methods

It is no secret that a significant cohort of both foreign and domestic politicians, scientists and practitioners have been actively working on the issue of low-carbon production for more than a year (Foxon, 2011; Liu, *et al.*, 2020; Liu, Xu, & Hao, 2021; Lu, & Sun, 2021; Shuai, *et al.*, 2019; Zhangping, & Yintai, 2008; Zhang, *et al.*, 2019; Wu, *et al.*, 2020; Taghizadeh-Toosi, & Olesen, 2016; Nyambuu, & Semmler, 2020; Zhan, & de Jong, 2018; Slobodanyk, & Abuselidze, 2019). In particular, UN Secretary-General Antonio Guterres emphasizes that existing climate threats, biodiversity crises and environmental pollution require humanity to reflect on the true value of nature. Humanity will ensure the well-being of the planet, and hence the well-being of present and future generations because this is achieved only by understanding its value and directing ingenuity to the transition to low-carbon production (UNEP, 2021a).

Michael R. Bloomberg, with ten years of experience in combating climate change, emphasizes that the transition to low-carbon production and achieving neutral greenhouse gas (GHG) emissions by 2050 (while changing the biodiversity loss curve) is vital and is a fundamental basis in solving the climate problem of the planet and achieving the goals of sustainable development set by the UN in the medium and long term (Michael).

Patricia Espinosa proves the need to mobilize government, business and citizens as soon as possible to achieve carbon neutrality (UNEP, 2021b). Inger Andersen emphasizes the importance of unity in finding political, economic and innovative solutions to overcome environmental crises related to GHG emissions (UNEP, 2021a).

Richardson K., Steffen W. and Liverman D. argue that the transition to low-carbon production is extremely necessary, but its implementation requires large amounts of investment, which is complicated by their deficit, especially in developing countries (Richardson, Steffen, & Liverman, 2011).

In particular, authors (Carraro, Favero, & Massetti, 2012; Owen, Brennan, & Lyon, 2018; Campiglio, 2016; Monnin, 2018; Abuselidze, 2019) talk about the importance of macroprudential financial regulation in the development of credit policy by banks and the limitations and challenges facing low-carbon enterprises. Due to the fact that low-carbon activities require additional tools, banks refuse low-carbon lending.

Hahnel R. in his work "Green in Economics:

Confronting the Ecological Crisis" argues that innovation and investment should be directed primarily to those activities that protect both people and the environment (Hahnel, 2014). However, we consider such statements to be erroneous, there should not be individual industries, regions, cities or enterprises in which it is worth investing and in which they are not. Authorities, businesses and the public in all countries of the world must be united in overcoming the threats of climate change and the transition to low-carbon production.

I.P. Haidutskyi argues that anti-carbon policy should be unified, global and mandatory. Ensuring low-carbon development with sufficient capital is possible provided that the policies of all parties involved are consistent: international institutions; transnational companies, governments of recipient countries, etc. Policy coherence is the fundamental basis that can ensure the effectiveness of the anti-carbon mechanism and thus can accelerate the transition to low-carbon production (Haidutsky, 2017). In certain economic situations, additional policies are required to increase competition in the banking system and to expand lending to low-carbon activities (Campiglio, 2016; Monnin, 2018; Abuselidze, & Kizinidze, 2019; Abuselidze, 2021; Louche, & Marcus, 2019). For example, by differentiating reserve requirements for the purpose of lending, it is possible to create loans for the low carbon sectors. This is possible in developing market economies, where a wide range of monetary policy instruments are represented and the central bank oversees the distribution of credit. Consequently, the issue of finding ways to enhance the effectiveness of this mechanism is topical and requires an immediate search for ways to address them.

Therefore, the aim of the study was to find ways to increase the effectiveness of the coordination mechanism to accelerate the transition to low-carbon production, which in the context of intensifying climate change will ensure the environment, well-being of the planet and their future generations.

The following methods are used in the course of the research: economic and mathematical modeling – in determining the dependence of GHG emissions on the volume of gross output of agricultural production and capital investment, the area of agricultural coal and livestock; decoupling analysis – when assessing the impact of agribusiness on the environment; strategic analysis – in assessing the feasibility of the chosen strategy of low-carbon agricultural production; GAP-analysis – in finding ways to achieve the goals of low-carbon agricultural production; forecasting – when determining the volume of GHG emissions under the condition of increasing the volume of agricultural production; abstract and logical – in generalizing the results of the study and formulating conclusions.

## Results and Discussion

The results of research show that Ukraine has not been left out in resolving the issues of low-carbon production. With the ratification (On ratification of the UN Framework Convention on climate change, 1996) of the UN Framework Convention on Climate Change (UNFCCC) (United nations, 1992), Ukraine acceded to the UNFCCC member states and undertook a set of measures to reduce GHG and periodically publish information on emissions in the National Inventory of Anthropogenic Emissions from sources and removals by sinks of GHG in Ukraine (hereinafter – the National Inventory of Anthropogenic Emissions), formed in accordance with the requirements of the Secretariat of the UN Framework Convention on Climate Change (United nations, 1992).

According to the results of the last inspection by the UNFCCC Secretariat of the National Anthropogenic Emission Inventory, carried out in accordance with decisions 20 / CP.21 and 10 / CMP.11 of the Conferences of the UNFCCC Parties and the Paris Agreement (United Nations, 2015), Ukraine has demonstrated full compliance in the first years. However, we consider it appropriate to emphasize that the most significant decline in GHG emissions in Ukraine was observed during 1990-2000. A detailed study of the basis of these changes in volumes suggests that the reason was not modernization of production and implementation of innovative projects, but the decline of the Ukrainian economy, which led to a dramatic decline in production. A striking example

of this is agricultural production, changes in GHG emissions, which we have the opportunity to clearly observe the data in Figure 1.

According to Figure 1 during 1990-2000, GHG emissions from agribusiness decreased many times. At the same time, since 2000 until now a clear tendency of changes in GHG emissions has not been formed. Their volumes from year to year fluctuate with insignificant amplitude. The only thing that is clearly observed in this direction is the increase in carbon emissions from the crop industry while reducing the volume of these emissions from the livestock industry.

According to the National Anthropogenic Emissions Inventory (Ministry of Energy and Environmental Protection of Ukraine, 2019), total GHG emissions in the sector “Agriculture” in 2018 increased by 7.7% compared to the previous year. However, in 2019 their volumes decreased slightly. According to (Ministry of Energy and Environmental Protection of Ukraine, 2019), the largest increase in GHG emissions is observed in crop production, namely in the category “Agricultural soils”. Thus, compared to 1990, GHG emissions in this category decreased by only 11.1%, and compared to the previous 2017 – increased by 12.7%. This dynamic is explained by the growth of areas occupied by arable land, an increase in the amount of mineral fertilizers making the transition to a more unsustainable use of soils with lower rates of organic fertilizers.

Changes in GHG emissions from livestock have resulted in a reduction in the number of farm animals,

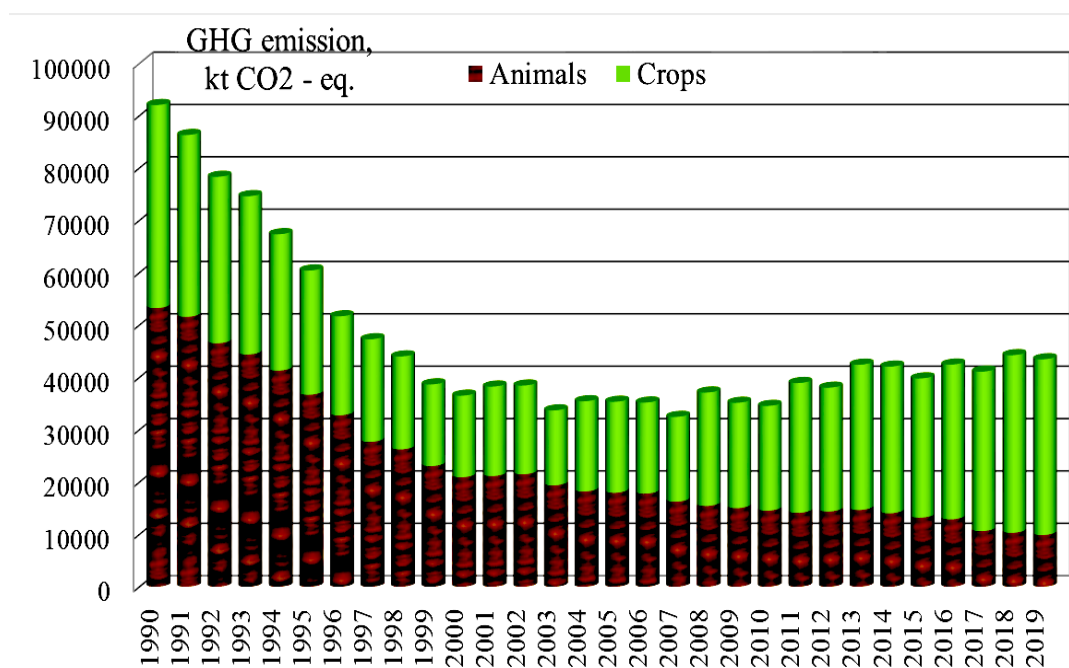


Figure 1. Emission Trends of GHG, kt CO<sub>2</sub>-eq.



in particular cattle, which has led to a reduction in emissions under the category “Intestinal fermentation” and, accordingly, under the category “Cleaning, storage and use of manure”. In some years, namely during 2000-2002, there was a slight fluctuation in these categories of GHG emissions due to the stabilization of the pig industry due to increasing the volumes of subsidies to the industry.

However, already in 2003, extreme weather conditions (intense cold and a small amount of snow), which led to deep freezing of the land and a significant reduction in forage yields, contributed to a reduction in animal populations and, consequently, to GHG emissions by definite categories.

The transition of agricultural enterprises from liquid manure to solid manure storage also encouraged the reduction of GHG emissions in the category “Cleaning, storage and use of manure”. Thus, the percentage of cattle manure stored by agricultural enterprises in liquid systems in 1990 was 21.0% of the volume of manure produced during the year, and in 2018 – only 5.1%. And since the potential for methane production in liquid manure storage systems is much higher than in its storage in solid form, the volume of emissions for the period 1990-2018 has decreased several times (Ministry of Energy and Environmental Protection of Ukraine, 2020, p.141).

Significantly, in 2018 GHG emissions in the category “Urea application” decreased by 60.7%. It is explained by the decrease in the volume of urea application to agricultural soils. The abandonment of the practice of soil liming has led to a reduction in GHG emissions in the category “Liming” by 94% compared to 1990 and by 3% compared to 2018 (Ministry of Energy and Environmental Protection of Ukraine, 2020, p.141).

However, we note that the data of the National Inventory of Anthropogenic Emissions, compiled in accordance with the requirements of the Secretariat of the UN Framework Convention on Climate Change, allow only to state the fact of anthropogenic emissions, without linking them to changes in production, which significantly complicates the formation of clear an idea of the state of the country's transition to low-carbon production.

We consider it possible to have a realistic assessment of the situation under the condition of introduction of state decoupling audit of low-carbon production, which should be based on uniform methodological principles, the application of which will determine the creation of a system of interconnected analytical data that will reproduce the dynamics and structural changes that occur in production under the influence of investment and innovation factors.

The concept of “decoupling” in domestic practice

has not yet been widely used. Interpretations of its substantive component are mainly based on the etymology of the borrowed English term. In particular, on the submission of its content in the Millennium Declaration, approved by the UN General Assembly Resolution of 08.09.2000 by no. 55 / 2 (Resolution, 2000), in The European Commission proposed a Strategy on the Sustainable Use of Natural Resources used in Europe (The European Commission proposed a Strategy on the Sustainable Use of Natural Resources used in Europe, 2005) of 25.12. 2005. As well as in The Roadmap to a Resource Efficient Europe (2011) (The Roadmap to a Resource Efficient Europe, 2011), where decoupling is seen as a break between the “negative environmental impact” and “economic benefits”.

Instead, with the formation of the Assessment of resource efficiency indicators and targets (Final report – 2012) and with the beginning of the UNEP report Decoupling Natural Resource Use and Environmental Impacts from Economic Growth, the concept of “decoupling” has become more broadly interpreted, namely as a key principle related processes of economic growth, the volume of consumed natural resources and environmental pollution, which provides for the growing needs of society while minimizing the load (Tkachenko, *et al.*, 2019). Therefore, the implementation of the decoupling audit will allow us to monitor compliance with the commitments of countries to transition to low-carbon production.

The decoupling audit should be based on the OECD method (OECD, 2001; Zhang, 2020; Zhang, Gu, & Guo, 2020) for estimating the effect of decoupling by the decoupling index (hereinafter – the Decoupling Index) and the decoupling factor (hereinafter – the Decoupling Factor), which is characterized by the following indicators:

Impact decoupling – decoupling by nature load (the level of impact of the industry or production on the environment);

Resource decoupling – decoupling by nature-intensive industry (the level of use of natural resources) (OECD, 2001).

Impact decoupling is determined by the formula:

$$DecIndex = \frac{\left(\frac{EP}{DF}\right)_{ending}}{\left(\frac{EP}{DF}\right)_{beginning}} = \frac{K_{EPending}}{K_{DFbeginning}} \quad (1)$$

Where:

*DecIndex* is decoupling index;

*EP* – environmental pressure, the indicator of anthropogenic pressure on the environment, natural units;

*DF* – driving force, an indicator of economic growth, are reflected in gross output, natural units;

Table 1

**Emission Trends GHG kt CO<sub>2</sub>-eq emissions by source categories**

Years	GHG source categories in the Agricultural sector of Ukraine					
	A. Enteric fermentation	B. Manure management	C. Rice cultivation	D. Agricultural soils	G. Liming	H. Urea application
1990	45924,87	7308,44	216,43	35709,95	2592,08	270,14
1991	44560,91	7002,18	176,94	32979,23	1351,26	229,79
1992	40442,07	6059,95	185,58	30090,36	1351,26	189,44
1993	38741,3	5618,85	176,55	28577,34	1351,26	149,09
1994	36179,91	5103,35	168,57	24426,56	1351,26	117,71
1995	32063,18	4608,23	165,17	22140,14	1351,26	86,33
1996	28741,84	3998,56	172,28	18398,56	299,2	54,95
1997	24479,96	3183,73	167,36	19313,71	76,41	61
1998	23270,76	2977,44	154,43	17459,45	77,79	59,96
1999	20270,36	2772,65	163,47	15335,41	70,63	48,27
2000	18468,6	2441,46	187,12	15264,85	63,47	82,2
2001	18746,74	2399,3	140,86	16769,07	71,47	117
2002	18926,94	2556,43	140,75	16647,36	53,78	116,91
2003	16984,02	2372,71	166,13	13927,54	49,37	191,1
2004	16016,58	2179,28	158,16	16962,84	83,33	35,83
2005	15719,51	2222,95	158,57	17011,59	90,92	138,32
2006	15460,79	2314,25	161	16979,44	105,99	171,32
2007	13998,08	2244,39	156,72	15731,11	112,35	212,11
2008	13241,48	2187,15	146,85	21054,47	124,95	355,18
2009	12767,38	2251,1	181,97	19622,78	151,88	175,03
2010	12191,9	2334,19	217,31	19348,96	127,46	334,73
2011	11784,12	2317,52	219,98	24080,83	127,16	391,52
2012	12016,15	2357,81	191,74	22948,71	161,72	351,36
2013	12257,78	2407,11	179,32	27008,06	182,25	381,75
2014	11681,1	2344,2	75,58	27413,42	156,26	386,03
2015	10970,24	2224,99	86,7	25979,33	169,83	372,5
2016	10752,01	2126,43	89,07	28876,25	140,09	457,62
2017	8597,04	2022,17	94,11	29697,25	168,6	512,07
2018	8298,21	2002,73	93,58	33479,29	163,74	201,18
2019	7918,02	1958,37	94,83	33004,02	163,23	316,84

Source: author calculation based on Ministry of Energy and Environmental Protection of Ukraine.

$K_{EP}$ ,  $K_{DF}$  – growth rates of relevant indicators.

When assessing the decoupling effect, the values of indicators in the reporting (ending) and base (beginning) periods of the study (years) should be taken into account.

$$DecFactor = 1 - DecIndex \quad (2)$$

Where:

$DecFactor$  is decoupling factor.

$Resource\ decoupling$  is calculated by the formula:

$$DecIndex = \frac{\left(\frac{N}{DF}\right)_{ending}}{\left(\frac{N}{DF}\right)_{beginning}} = \frac{K_{Nending}}{K_{DFbeginning}} \quad (3)$$

Where:

$N$  is the amount of used resources of the enterprise or industry, natural units;

$K_{EP}$  – the corresponding growth rate.

To convince of the expediency of introducing a state decapitation audit, we will study the changes in GHG emissions by agribusiness, which according to the National Inventory of Anthropogenic Emissions (Ministry of Energy and Environmental Protection of Ukraine, 2019) entered the TOP-10 leaders in air pollution. In the process of research we will focus on the studied impact and resource decoupling of GHG emissions both in the field of crop production and in the field of animal husbandry for the period from 1990-2019.

For this purpose, to calculate – chain growth rates of GHG emissions in crop production and – chain growth rates of GHG emissions in livestock, we will use the data of the National Inventory of Anthropogenic Emissions (Ministry of Energy and Environmental Protection of Ukraine, 2019), the Draft Annual National Inventory Report for Submission under the United Nations Framework Convention on Climate Change

and the Kyoto Protocol for the period 1990-2018 (hereinafter - Annual National) (Ministry of Energy and Environmental Protection of Ukraine, 2020) and data from the State Statistics Service of Ukraine (Prokopenko, 2020).

In this study, GHG in crop production will be carried out in the categories of Rice cultivation, Agricultural soils, Liming, as well as Urea application, and in animal husbandry – by the categories of enteric fermentation and Manure management (Table 1).

Perform single factor analysis of variance (ANOVA) in order to analyze the differences among means in the sample, according to Table 1, the objective of which, in conventional terms, is as follows: to single out three particular variances from the general variance of the parameter:

- The variance determined by the influence of each of the values under consideration;
- The variance dictated by the interconnection between the values under consideration;
- The random variance dictated by all the unconsidered circumstances.

The results of ANOVA are given in Table 2 and 3.

Since the  $F = 119.891$  exceeds the critical level of the  $F_{critical} = 2.266$ ,

Since  $F$  statistics ( $F = 119.891$ ) for the «GHG source categories» factor, exceeds the critical level  $F_{crit} = 2.266$ , this factor does have an impact on the «GHG emissions» parameter under analysis. In other words, we reject the null hypothesis about the equality of means in all classes of factor gradation (groups). Consequently, we conclude that GHG emissions, depending on the sources, differ significantly. This requires an in-depth detailed study by source categories, which is what we will do in animal husbandry – by source categories A and B, and in crop production – by source categories C, D, G and H (unlike research (Tkachenko, *et al.*, 2019).

Table 2

### ANOVA: Single-Factor Summery

Groups - GHG Source categories in the Agricultural sector of Ukraine	Count	Sum	Average	Variance
A. Enteric fermentation	30	601471.9	20049.06	126319661.1
B. Manure management	30	93897.92	3129.93	2403263.04
C. Rice cultivation	30	4687.13	156.23	1562.05
D. Agricultural soils	30	686237.9	22874.59	41900729.87
G. Liming	30	12340.26	411.34	386810.03
H. Urea application	30	6567.28	218.90	18523.98

Table 3

**ANOVA: Single-Factor Report (alfa = 0.05)**

Source of Variation	SS (Sum of Squares)	Df (Degrees of Freedom)	MS (Mean squares)	F	P-value	F crit
Between Groups	17087536245	5	3417507249	119.89	1.84064E-54	2.266
Within Groups	4959885953	174	28505091.7			
Total	22047422198	179				

Table 4

**Dynamics of indices of changes in agribusiness during 1990-2019**

Years	Indices to the previous year, %							
	gross output			of land	growth of animals and birds	emission trends GHG		
	of agricultural production	include				agribusiness of all	include	
		of crop production	of animal production				of crop production	of animal production
1991	86.8	83.3	90.5	99.95	96.43	93.78	89.55	96.86
1992	91.7	100.1	83.5	100.34	90.53	90.75	91.59	90.18
1993	101.5	110.4	91.1	99.92	92.03	95.27	95.08	95.39
1994	83.5	77.3	92.3	99.91	87.98	90.26	86.15	93.06
1995	96.4	102.6	89	99.96	89.86	89.70	91.09	88.82
1996	90.5	91	89.7	99.94	85.74	85.51	79.70	89.28
1997	98.2	105.8	87.6	99.98	88.99	91.51	103.66	84.49
1998	90.4	83	102.8	99.92	100.84	93.05	90.48	94.88
1999	93.1	89.9	97.4	99.99	96.06	87.86	87.97	87.78
2000	109.8	121.3	95.3	99.97	90.74	94.43	99.87	90.74
2001	110.2	112.3	106.8	99.95	107.36	104.75	109.62	101.12
2002	101.2	98.5	105.7	99.96	105.22	100.51	99.18	101.59
2003	89	85.9	93.9	99.96	89.64	87.64	84.52	90.1
2004	119.7	133.1	100.5	99.94	98.01	105.17	120.27	94
2005	100.1	97.5	105.1	99.89	103.21	99.73	100.92	98.6
2006	102.5	101.8	103.6	99.88	103.54	99.57	100.1	99.06
2007	93.5	90.9	98	99.94	95.40	92.21	93.07	91.37
2008	117.1	128.6	98.7	99.94	99.26	114.34	133.73	94.98



2009	98.2	95.3	104.2	99.92	107.3	94.71	92.85	97.34
2010	98.6	96.4	104.3	99.94	103.0	98.3	99.48	96.72
2011	120.2	128.7	99.8	99.96	96.94	112.63	123.92	97.07
2012	96.1	93.3	104.9	99.95	104.86	97.7	95.3	101.93
2013	113.6	117.1	103.9	99.97	104.57	111.54	117.32	102.02
2014	102.2	103.1	99.5	99.96	90.71	99.15	101.0	95.63
2015	95.2	94.8	96.4	99.98	96.01	94.64	94.92	94.08
2016	106.3	109.1	97.3	99.95	97.41	106.62	111.1	97.59
2017	97.8	97.1	100.2	99.95	97.63	96.81	103.07	82.45
2018	108.2	110.2	101.2	99.62	100.14	107.65	111.37	97.0
2019	101.4	101.8	100.2	99.95	99.12	98.22	98.94	95.87

We will use the data of chain growth indices for, in our opinion, priority factors of influence to carry out a decoupling audit (Table 4).

The comparison of the dynamics of *impact decoupling indicators*, namely  $K_{EPa}$  and  $K_{DFa}$  by the growth rate of gross livestock production is shown in Figure 2a, and according  $K_{EPc}$  and  $K_{DFc}$  – by the growth rate of gross crop production – in Figure 2b.

We use the classification of decoupling types according to P. Tapio (2015) to describe the decoupling effect, which distinguishes between *coupling*, *decoupling* and *over coupling* (Figure 3).

Coupling effect is observed under the condition of approaching the rates of economic growth to the rates of changes in GHG emissions. At the same time, it can be:

Expansive coupling effect – if the rate of economic growth and GHG emissions tend to increase;

Recessive coupling effect – if the rate of economic growth and GHG emissions tend to decrease.

However, in both cases the *coupling effect* is present only if *DecIndex* is in the range of  $0.8 < DecIndex < 1.2$ .

*Decoupling effect* is observed in the presence of a gap between the rate of economic growth and the rate of change of GHG emissions. At the same time, it can be:

*weak decoupling effect* under the condition of simultaneous growth of economic growth rates and GHG emissions, but when the growth rates of the former exceed the latter, i.e. when *DecIndex* is in the range  $0 < DecIndex < 0.8$ ;

*strong decoupling effect* under conditions of growth of economic growth rates and simultaneous decrease in rates of GHG emissions, i.e. when *DecIndex* is in the range of *DecIndex* < 0;

*recessive decoupling effect* with a simultaneous

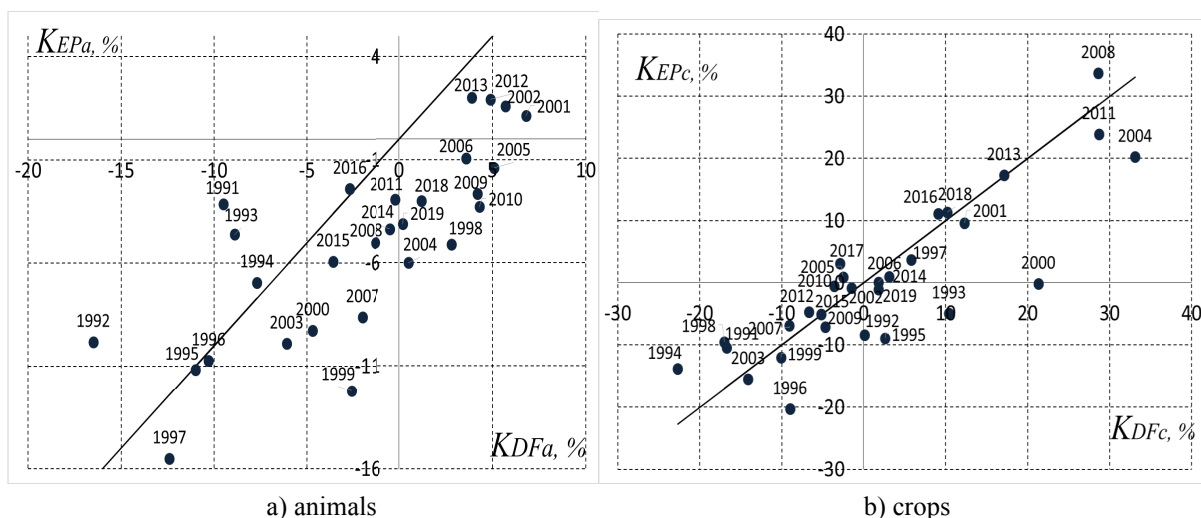


Figure 2. Dynamics of growth rates of impact decoupling indicators on agribusiness of Ukraine during 1990-2019.

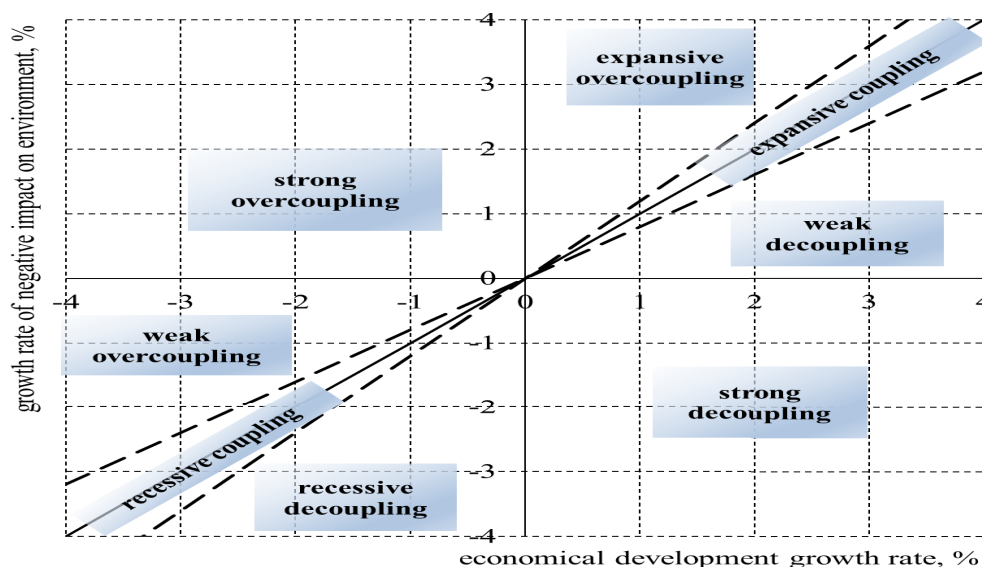


Figure 3. Classification of types of decoupling effect.

decline in economic growth and GHG emissions, but when the rate of decline in GHG emissions exceeds the rate of decline in economic growth, i.e. when  $DecIndex$  is in the range of  $DecIndex > 1.2$ ;

*Overcoupling effect* is observed in the negative nature of the gap between economic growth and GHG emissions. It can be:

*weak overcoupling effect* is observed if the rate of economic growth and the rate of change of GHG emissions tend to decline, but when the rate of decline of economic growth exceeds the rate of decline of GHG emissions, i.e. when  $DecIndex$  is in the range  $0 < DecIndex < 0.8$ ;

*strong overcoupling effect* is observed if the rate of economic growth tends to decline, and the rate of change in GHG emissions to increase when  $DecIndex$  is in the range  $DecIndex < 0$ ;

*expansive overcoupling effect* is observed if the rate of economic growth and the rate of change of GHG emissions tend to increase, but when the growth rate of the latter exceeds the former, i.e. when  $DecIndex$  is in the range of  $DecIndex > 1.2$  (Arsakhanova, Khazhmuradov, & Khazhmuradova, 2019).

Therefore, according to Figure 2a livestock of the 1990s is characterized by a *weak overcoupling effect*, which resulted from a decline in gross output due to a reduction in livestock numbers and negligent treatment of intestinal fermentation, as well as the widespread use of manure as organic fertilizer, accompanied by rising GHG emissions. There has been a steady decline in livestock to this day, but since 1997, the industry has been accompanied by a *recessive decoupling effect*, which in some years of the first decade of the XXI century gradually transformed into

a *weak decoupling* and *strong decoupling effect*, which is explained by the gradual increase in gross output due to rising prices and declining GHG emissions due to declining livestock numbers.

It is quite difficult to characterize the phenomenon of decoupling in crop production during the period studied according to Figure 2b, because significant dependence of gross output on climatic conditions, as well as changes in world prices for grain and other agricultural products, the loss of trade ties with Russia due to military-political conflict in eastern Ukraine, etc. became an obstacle formation of certain trends. Consequently, the decoupling effect during 1990-2019 in the field of crop production changed quite chaotically. However, the importance of crop production in the total GHG emissions by agribusiness continues to grow every year, which, as noted earlier, is due to the high percentage of arable land in the structure of agricultural land.

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We will use an integrated approach to assess changes in GHG emissions in agriculture as a whole. The calculation of the integrated *impact decoupling* of agribusiness in Ukraine during 1990-2019 can be done by  $K_{EPI}$ , determined using the geometric mean value of GHG emission growth indices in livestock and crop production, as well as  $K_{DFI}$  – chain growth rates of gross output of agribusiness, in % (Figure 4).

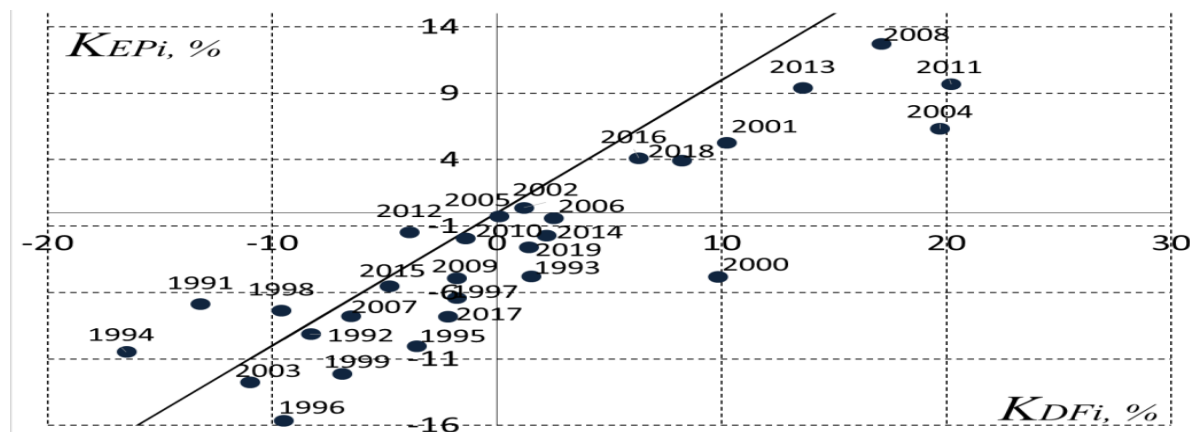


Figure 4. Dynamics of growth rates of integrated impact decoupling in agribusiness of Ukraine during 1990-2019.

The data of Figure 4 convincingly show that the chaos decoupling effect in the field of crop production has left its mark on the decoupling effect on agribusiness in general. However, in the vast majority of years during the period under study, agricultural production is accompanied by a *weak decoupling effect*, which is gradually transformed into a *strong decoupling effect*, and vice versa. That is, the level of natural load of agricultural production during 1990-2019 is characterized by certain instability, and therefore, the clarity of the transition of agribusiness in Ukraine to low-carbon production is still not observed.

To convince of the correctness of this statement, we additionally analyse the decoupling effect on *resource decoupling* indicators, namely by comparing the dynamics of *resource decoupling* indicators, namely  $K_{DFa}$  and  $K_{Na}$  the chain growth rate of livestock, the results of which are presented in Figure 5a, and  $K_{DFx}$  also  $K_{Nc}$  and – chain growth rate of agricultural land,

the results of which are presented in Figure 5b. In this case, we will use an integrated approach to determine  $K_{Na}$  and calculate with the help of the geometric mean of the growth indices of the number of animals and poultry.

Analysing the data in Figure 5a, we have reason to state that the change in the number of livestock in the vast majority of years during the study period was accompanied by positive changes in the decoupling effect. However, the first years of independence (1991-1997) were quite difficult for livestock, and therefore accompanied by a weak overcoupling effect, as a result of a simultaneous decline in economic growth and the rate of change in GHG emissions in excess of the rate of decline of the latter.

Budget support for the industry, which became more active during 2006-2012, helped to improve the situation in animal husbandry – to increase production volumes while increasing GHG emissions. However,

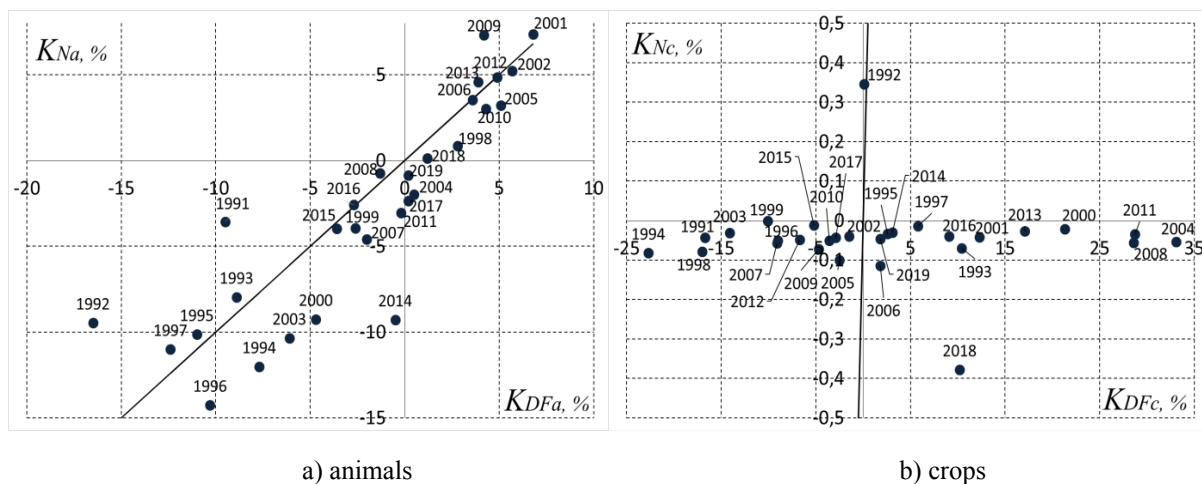


Figure 5. Dynamics of growth rates of resource decoupling indicators in agribusiness of Ukraine during 1990-2019.

the growth rate of the latter over the rate of change in economic growth has led to the expansion of the industry of expansive overcoupling effect.

2015-2016 years were no less difficult. These were the years of difficult epizootic situation, when due to high production costs, declining demand due to changing consumer preferences for the main types of livestock products, low sales prices and limited sales. Thus, most farms in the livestock industry could not reach even the threshold of profitability (break-even), which forced them to further reduce livestock and led to the support of livestock strong overcoupling effect, as a result of declining economic growth against the background of growing GHG emissions.

Studying resource decoupling in crop production, it should be noted that according to Figure 5b during 1990-2019 the industry was accompanied by both the phenomenon of strong decoupling effect and the phenomenon of weak overcoupling effect, which is primarily due to minor changes in agricultural land. Transformation from one to another decoupling effect took place under the influence of natural and climatic conditions, changes in the structure of sown areas, the amount of mineral and organic fertilizers, technologies used for land cultivation, etc.

To determine the integrated resource decoupling in the agribusiness of Ukraine as a whole, by analogy with previous calculations, we use an integrated approach, according to which is determined by the geometric mean of the growth indices of livestock and poultry, as well as – by the geometric mean of the growth indices area of agricultural land (Figure 6).

The obtained calculated values of the decoupling index according to formulas (1) – (3), the dynamics of which is shown in Figures 2, 4-6, are summarized in Table 5.

The data in Table 5 and Figure 6 prove once again that the agribusiness of Ukraine during 1990-2019 was accompanied by a different decoupling effect, which we consider natural, because in agribusiness, as well as in the Ukrainian economy as a whole during the studied period as a result of transformational changes, military and political conflict in eastern Ukraine and other upheavals, there were both recessions and growth. Until then, the expectation of a quick return to the results of the transition of agribusiness to low-carbon production is considered unrealistic.

Of course, the country has set ambitious goals for 2030 and 2050, an anti-carbon policy is formed, an anti-carbon strategy is defined, and, therefore, the only thing is to wait for their implementation. Indicators of resource decoupling in recent years show positive changes, namely the support of agribusiness in 2016-2018 weak decoupling effect, and in 2019 – strong decoupling effect. Therefore, we believe that in the coming years we will still be able to more clearly observe the transition of domestic agribusiness to low-carbon production. Achieving the ambitious goals set for the period 2030-2050 is known to be possible with the necessary investments to modernize production and implementation of innovative projects.

A correlation and regression analysis was performed for both livestock and crop production to establish the impact of investments on the rate of change in GHG emissions. After smoothing the time series, an optimization selection of nonlinear functional dependences of multifactor regression models was performed. That was done for the greatest correspondence to the initial data. After linearization, the regression coefficients are determined by the generalized least squares method in matrix form:

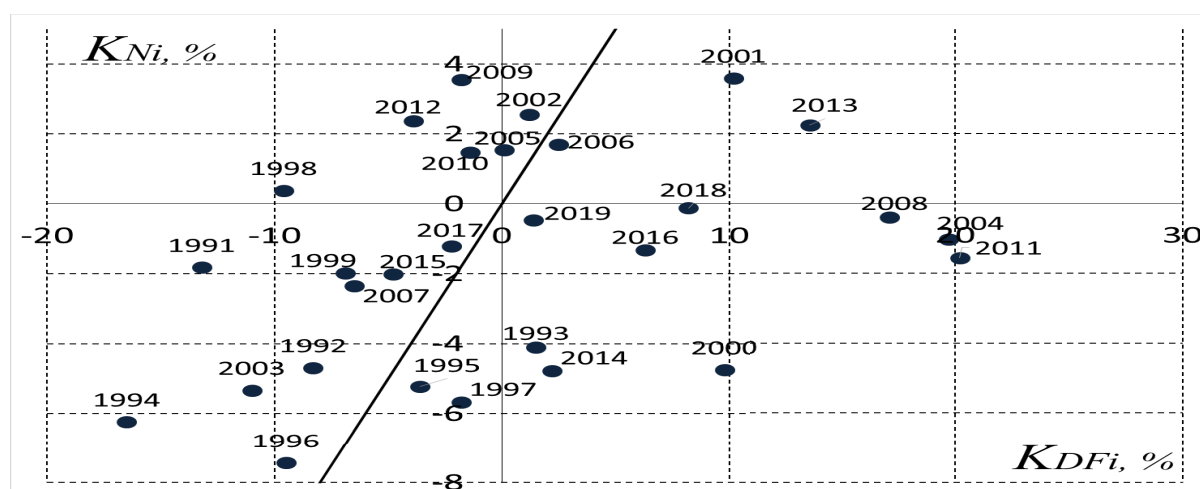


Figure 6. Dynamics of growth rates of integrated resource decoupling in agribusiness in Ukraine during 1990-2019

Table 5

**The results of the calculation of decoupling indices**

Years	Impact DecIndex of Animal husbandry	Impact DecIndex of Crop production	Integral Impact DecIndex of agribusiness	Recourse DecIndex of Animal husbandry	Recourse DecIndex of Crop production	Integral Recourse DecIndex of agribusiness
1991	0.33	0.62	0.519	0.375	0.002	0.137
1992	0.59	-84.07	1.098	0.573	3.457	0.564
1993	0.51	-0.47	-3.172	0.895	-0.006	-2.732
1994	0.90	0.61	0.633	1.560	0.003	0.378
1995	1.015	-3.42	2.790	0.921	-0.012	1.450
1996	1.04	2.25	1.646	1.384	0.005	0.781
1997	1.25	0.63	3.561	0.887	-0.002	3.150
1998	-1.82	0.56	0.764	0.301	0.004	-0.039
1999	4.69	1.19	1.755	1.513	0.0001	0.288
2000	1.96	-0.006	-0.490	1.969	-0.001	-0.484
2001	0.16	0.782	0.518	1.083	-0.003	0.352
2002	0.27	0.544	0.318	0.916	0.026	2.132
2003	1.62	1.097	1.157	1.697	0.002	0.484
2004	-11.99	0.612	0.321	-3.965	-0.001	-0.051
2005	-0.27	-0.369	-2.412	0.631	0.040	15.451
2006	-0.25	0.058	-0.166	0.983	-0.063	0.678
2007	4.31	0.760	1.196	2.297	0.006	0.362
2008	3.85	1.179	0.743	0.562	-0.002	-0.023
2009	-0.63	1.520	2.738	1.738	0.015	-1.971
2010	-0.76	0.142	1.361	0.699	0.014	-1.047
2011	14.61	0.833	0.479	15.257	-0.001	-0.077
2012	0.39	0.701	0.369	0.991	0.007	-0.609
2013	0.52	1.013	0.691	1.172	-0.001	0.165
2014	8.72	0.325	-0.778	18.575	-0.009	-2.168
2015	1.64	0.976	1.145	1.106	0.002	0.420
2016	0.89	1.220	0.656	0.958	-0.004	-0.209
2017	-87.71	-1.060	3.549	-11.806	0.015	0.549
2018	-2.49	1.115	0.480	0.117	-0.037	-0.014
2019	-20.61	-0.587	-1.858	-4.362	-0.026	-0.329



Where:

$$Ea = -16178.642 + \frac{127955.206}{Ia^{0.4}} + \frac{34109.784}{Sa^{0.2}} + 83.823 \cdot Va^{0.4} \quad (4)$$

$$Ec = -11837.504 + \frac{58526.761}{Ic^{0.2}} + \frac{65690.912}{Sc^{0.5}} + 43.902 \cdot Vc^{0.5} \quad (5)$$

$E_a$ ;  $E_c$  are volumes of GHG emissions into the atmosphere (GHG) from livestock and crop production correspondently, CO<sub>2</sub> – eq. thousand tons,

$I_a$ ;  $I_c$  are capital investments in animal husbandry and crop production, UAH million

$S_a$ ;  $S_c$  are current costs for environmental protection in animal husbandry and crop production, UAH million

$V_a$ ;  $V_c$  are volumes of gross livestock and crop production, UAH million

The calculated values of the Fisher's coefficients  $F_1=21.22$ ,  $F_2=34.76$ , and the critical level  $F_{cr}=2.98$  for the degrees of freedom  $k_1=3$ ,  $k_2=26$  and level of significance  $\alpha=0.05$ . Thus, Fisher's test,  $F_{1,2} > F_{cr}$ , showed that with 95% reliability we can assume that the proposed mathematical models are adequate to the statistic data and on the basis of the adopted models it is possible to evaluate the effectiveness of the coordination mechanism of agribusiness to low carbon production.

Graphs of the model (4) are shown in Figure 7a for

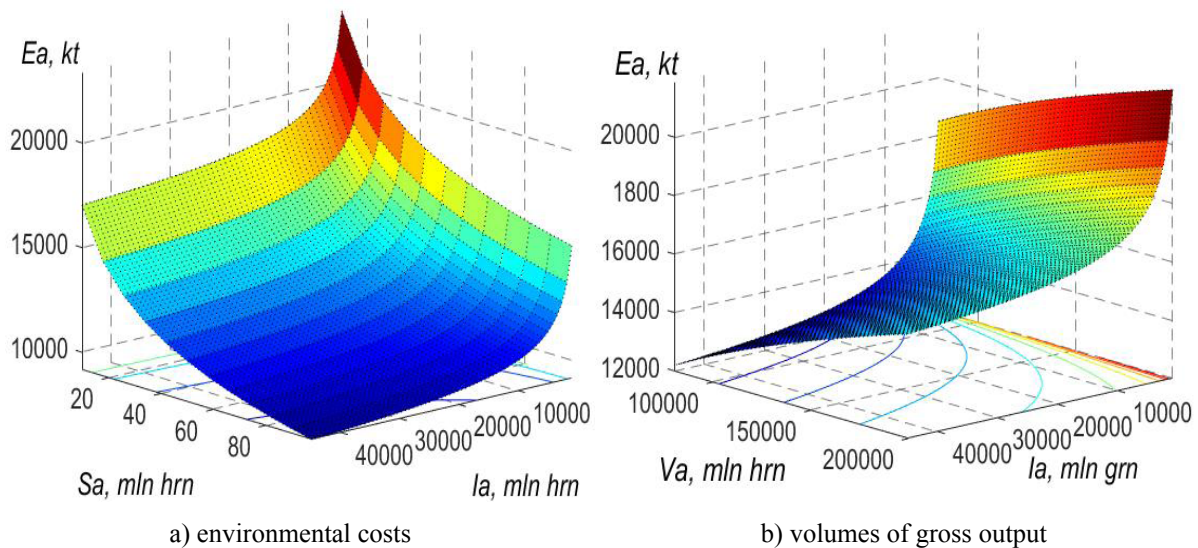


Figure 7. Dependence of livestock GHG emissions on capital investment in livestock agribusiness modernization

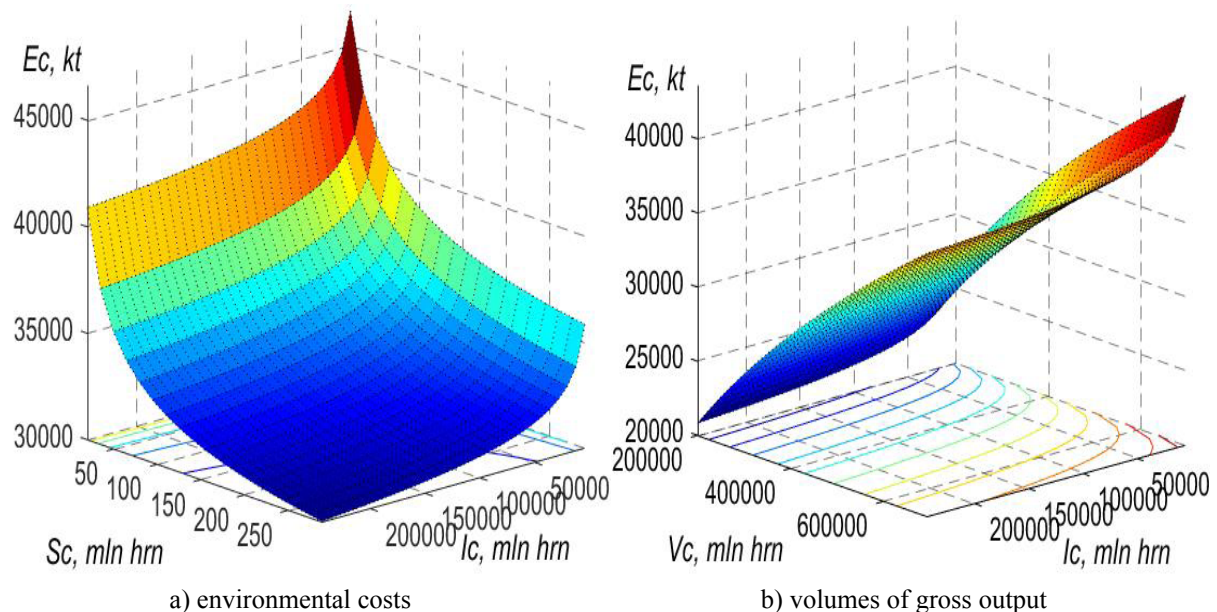


Figure 8. Dependence of crop production GHG emissions on capital investment in crop agribusiness modernization.

Table 6

**Results of modelling GHG emission scenarios for the second Nationally Determined Contribution of Ukraine to the Paris Agreement**

Scenarios	Indices of GHG emission reductions in agribusiness compared to 1990, %		Indices of growth of needs for capital investments in agribusiness relative to 2018, %		Growth indices of gross agribusiness production relative to 2018, %	
	2030	2050	2030	2050	2030	2050
1. BAU Scenario	48	48	120	152	107.8	120.7
2. Reference Scenario	46	44	156	176	111.2	127.8
3. Scenario of climate-neutral economy	44	40	172	370	117.6	131.2

the constant value of  $V_a = 153018.3$  million UAH and in Figure 7b for the constant value of  $S_a = 18.9$  million UAH.

Graphs of the model (5) are shown in Figure 8a for the constant value of  $V_c = 570636.6$  million UAH and for the constant value of  $S_c = 65.1$  million UAH in Figure 8b.

The images in Figures 7 and 8 convincingly show that with increasing capital investment and current expenditures on environmental protection, GHG emissions are declining. However, it should be remembered that as the food security problem worsens, the world expects Ukraine, as one of the leaders in the export of agricultural products, to increase production volumes, which will lead to an increase in GHG emissions. Therefore, when determining the liabilities for the second and subsequent nationally determined contributions to the Paris Agreement, it is necessary to take into account (United Nations, 2015) the dependence of GHG emissions on the volume of gross output.

Thus, the Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine within the EBRD Project "Support to the Government of Ukraine to update the nationally determined contribution" has developed models of GHG emissions in different economic scenarios (The Institute for Economics and Forecasting, NASU, 2020), the results of which for agribusiness are given in Table 6.

Forecasts for scenario 1 (*baseline scenario*) were based on past and current trends in agribusiness (The Institute for Economics and Forecasting, NASU, 2020, p.72), as well as on the current level of implementation of current legislation – its implementation only partially or with a significant delay (The Institute for Economics and Forecasting, NASU, 2020, p.6). According to this scenario, in the sector "Agriculture" it is expected that in 2030 the

volume of GHG emissions will be 52% lower than the volume of emissions in 1990 (The Institute for Economics and Forecasting, NASU, 2020, p.13).

At the same time, according to Scenario 2 (*reference scenario*), GHG emissions in this sector are expected to be about twice as low as in 1990, but about 7% higher than at the current level. In particular, the category "Intestinal fermentation" according to certain forecasts provides for a reduction in GHG emissions from internal fermentation to 20% from 1990 levels. A similar trend will occur in the category of "The handling of manure". Emissions from this category of GHG emission sources are expected at 30% of 1990 levels, due to a decrease in livestock compared to the base year, as well as an increase in the use of manure biogas plants and the use of additional substances in the diet of animals (The Institute for Economics and Forecasting, NASU, 2020, p.72).

Regarding the forecasts of GHG emissions from agricultural lands, it should be noted that in the coming years they are expected to increase due to the increase in arable land. However, they are projected to be lower than in the base year. Achieving the reduction of GHG emissions from agricultural land is expected by reducing the level of mineralization of agricultural soils, as well as the spread of new technologies in crop production, in particular, tillage with reduced reservoir turnover (or no turnover), which will reduce GHG emissions in the area up to 5 million hectares (The Institute for Economics and Forecasting, NASU, 2020, p.73).

Emissions in this sector until 2030 are projected to be similar to the trends and processes as in Scenario 1, but Scenario 2 includes full implementation of national anti-carbon policy and implementation of strategies such as "Low Carbon Development Strategy of Ukraine until 2050" (Handrich; A low carbon development strategy for Ukraine until 2050;

Table 7  
Forecasts of expected GHG emissions by crop production in 2030 and in 2050 under the EBRD Project

Indicators	2030 year			2050 year		
	I Scenario	II Scenario	III Scenario	I Scenario	II Scenario	III Scenario
<i>Ic</i> , million UAH	64952.9	84438.7	93099.1	82273.6	95264.2	200271.4
<i>Sc</i> , million UAH	65.1	84.7	93.4	82.5	95.6	200.8
<i>Vc</i> , million UAH	570636.6	588634.4	622512.7	638922.4	676506.1	694503.9
<i>Ec</i> in CO <sub>2</sub> - eq. thousand tons	18618.5	17842.8	17066.9	18618.5	17066.9	15515.4

Eyl-Mazzega, & Mathieu, 2019), “State Environmental Strategy by 2030” and others (The Institute for Economics and Forecasting, NASU, 2020, p.72).

Thus, according to Scenario 2 in the sector “Agriculture” for all categories of sources, it is expected to reduce GHG emissions in 2030 to 49% of 1990 levels and in 2050 – to 47% of 1990 levels (The Institute for Economics and Forecasting, NASU, 2020, p.75).

Forecasts under Scenario 3 (*climate-neutral economy scenario*) are based on the implementation of all measures identified in Scenario 2 and larger-scale implementation of advanced technologies that are not currently used in agribusiness due to the need for significant investment and lack of knowledge (The Institute for Economics and Forecasting, NASU, 2020, p.73).

Therefore, it is expected that GHG emissions in 2030 will be 47% of the 1990 level and in 2050 – 42% of the 1990 level (The Institute for Economics and Forecasting, NASU, 2020, p.75). Thus, the forecasts of expected emissions in crop and livestock production in 2030 and in 2050 in terms of natural units are characterized by the data given in Table 7 and 8.

For the crop sector, by 2030, Scenarios 2 and 3 envisage an increase in both capital investment and current expenditures on environmental protection, which is almost 1/3 higher than in 2018. At the same time, a slight increase in gross output is expected (up to 5% of the 2018 level) at a similar level of reduction of GHG emissions, which will provide support for this industry of *weak decoupling-effect*.

Scenario 2 until 2050 expects almost similar results as Scenario 3 until 2030. However, the deepening climate crisis requires more radical action to reduce GHG emissions. Therefore, Scenario 3 envisages an increase in capital investment and current environmental costs by almost three times by 2050 compared to their level in 2018. At the same time, the gross output is expected to increase to 694.503.9 million UAH, i.e. up to 10% from 2018 while reducing GHG emissions by more than 15% from 2018, which will provide support for this industry of *strong decoupling effect*.

Reduction of GHG emissions in the livestock sector is expected in the same way as in crop production, due to increased capital investment and

Table 8  
Forecasts of expected GHG emissions by livestock in 2030 and 2050 according to the EBRD Project

Indicators	2030 year			2050 year		
	I Scenario	II Scenario	III Scenario	I Scenario	II Scenario	III Scenario
<i>Ic</i> , million UAH	13117.9	17053.3	18802.4	16616.0	19239.6	40446.9
<i>Sc</i> , million UAH	18.9	24.7	27.2	24.0	27.8	58.5
<i>Vc</i> , million UAH	153018.3	157844.5	166929.1	171329.4	181407.6	186233.8
<i>Ec</i> in CO <sub>2</sub> - eq. thousand tons	25551.9	24487.3	23422.7	25551.9	23422.7	21293.3

Table 9

**Comparative analysis of forecasts of expected GHG emissions by agribusiness in 2030 and 2050 according to the EBRD Project and the author's methodology**

Indicators	2030 year			2050 year		
	I Scenario	II Scenario	III Scenario	I Scenario	II Scenario	III Scenario
GHG emissions under the EBRD Project	44,170.52	42,330.08	40,489.64	44,170.52	40,489.64	36,808.76
GHG emissions according to the author's method, total	42,730.31	40,845.4	41,001.29	42,561.64	42,353.94	37,246.63
including: in crop production	35,845.62	35,037.81	35,536.37	36,571.98	36,902.4	34,478.15
in animal husbandry	6,884.692	5,807.593	5,464.923	5,989.667	5,451.53	2,768.478

current environmental costs by almost 1/3 and the implementation of technologies for biogas production from manure, which will not only replace fossil fuels for energy goals, but also to reduce the level of GHG emissions from manure by 10% by 2030 (see Table 8) (The Institute for Economics and Forecasting, NASU, 2020, p.73).

At the same time, the implementation of technologies for biogas production from manure in the livestock sector according to Scenario 3 will not only replace fossil fuels for energy purposes, but also reduce GHG emissions by 50% by 2050 (The Institute for Economics and Forecasting, NASU, 2020, p.74). However, it should be recognized that Scenario 3 compared to others is more aggressive to changes in capital investment and current costs of environmental protection and provides for their increase compared to 2018 almost three times, i.e. up to 40446.9 million UAH and 58.5 million UAH in accordance.

If we summarize the required level of investment by year and estimate the difference between Scenarios 2 and 3, we can conclude that the level of investment in both crop and livestock will differ slightly by 2035. And only, starting from 2035 onwards, the level of required investments under Scenario 3 should be higher than under Scenario 2, mainly due to assumptions of rising prices for new technologies (The Institute for Economics and Forecasting, NASU, 2020, p.11). At the same time, the expected GHG emissions made by the forecasts within the framework of the EBRD Project are characterized by the data presented in Table 9.

However, the forecast calculations according to the proposed author's model show that the forecast calculations made by the Institute of Economics and Forecasting of the National Academy of Sciences of

Ukraine within (The Institute for Economics and Forecasting, NASU, 2020) are not realistic enough and will not provide the expected results in the future.

Our projected values exceed the indicators to be pursued under Scenario 3 by 2030 and, most importantly, in relation to Scenarios 2 and 3 by 2050. The simulation results showed that the identified amounts of capital investment and current environmental costs are insufficient to achieve ambitious goals, defined by the anti-carbon strategy of Ukraine and will not ensure the achievement, determined by the conclusions of the IPCC (Intergovernmental Panel on Climate Change), of the desired emission trajectory to curb global warming on the planet not higher than 1.5°C until 2030 and 2050.

This confirms that in the near future the focus on the full implementation of the anti-carbon policy of the Government of Ukraine and the planned measures is critical. Therefore, there is an urgent need to review capital investment in new innovative technologies, which are expected to become commercially available after 2030 and allow Ukraine to increase the level of ambition of its goals in the long run. Full implementation of existing strategies according to Scenario 2 and extrapolation of relevant targets by 2050 is an ambitious task itself and will require a multiple increase in investment in the agricultural sector to volumes comparable to the best examples of countries whose economies are developing rapidly.

Meanwhile, even such a long-term extension of policies with the current level of ambition will not be enough to stabilize GHG emissions, the level of which according Scenario 2 begins to grow moderately after 2035. Although Scenarios 2 and 3 are in fact superimposed on each other by 2030 and can only provide some information in the process of preparation



Table 10

**Forecasts of expected GHG emissions by agribusiness in 2030 and in 2050 with increased capital investment**

Indicators	2030 year			2050 year		
	I Scenario	II Scenario	III Scenario	I Scenario	II Scenario	III Scenario
GHG emissions according to the author's method, total	41,611.59	40,044.15	40,294.09	41,733.37	41,667.25	36,982.93
including: in crop production	35,231.62	34,607.4	35,159.56	36,126.1	36,537.24	34,346.64
in animal husbandry	6,379.976	5,436.746	5,134.522	5,607.276	5,130.017	2,636.289

of the 2<sup>nd</sup> National-Defined Contribution of Ukraine to the Paris Agreement (United Nations, 2015), in the long run the dynamics of GHG emissions under these scenarios significantly differs, which highlights the need for further analysis (The Institute for Economics and Forecasting, NASU, 2020, p.103).

According to the projected calculations of the author's method for Ukraine's transition to low-carbon production, capital investment in the agricultural sector of the economy should be increased by at least 15% compared to their volume projected until 2050 under Scenario 3, which will reduce GHG emissions accordingly to the ambitious goals set by the anti-carbon policy of Ukraine and the Strategy of low-carbon development of Ukraine until 2050. Given the increase in capital investment, the expected GHG emissions in agribusiness as a whole and in crop production and animal husbandry will be characterized by the forecasts presented in Table 10.

Forecasts of GHG emissions by the crop industry are many times higher than GHG emissions by the livestock industry. With a constant area of agricultural land, namely the area of arable land, it is possible to reduce emissions in crop production due to the expansion of organic production and the wider use of technologies for minimal tillage.

Organic production, combining high quality standards and best environmental practices, contributes to both the conservation of natural resources and biodiversity, and the reduction of GHG emissions. According to research conducted within the project "Assessment of technological needs in Ukraine", organic production can occupy up to 4 million hectares. Currently, the area under organic production is only 309 thousand hectares and therefore, domestic agribusiness has significant potential for its implementation. At the same time, the potential for the

introduction of technologies of minimum tillage, according to the same study, can reach 10 million hectares (European Green Deal, 2020).

In order to create the necessary information support for the decoupling audit, we consider it expedient to supplement the GRI 300 "Environmental Disclosures" (The Global Reporting Initiative 300, 2017), which are currently being adapted, with the group of indicators GRI-305.5 "Reduction of GHG emissions" in the preparation of the second National Determined Contribution to the Paris Agreement, formed by the decoupling approach, which will ensure control over compliance with the commitments made by each of the enterprises, and hence by each industry and country to implement the transition to low-carbon production.

## Conclusions

Thus, the study found that the strategic focus of transformational changes in the economy is currently chosen low-carbon production, the achievement of which is possible with the consistent application of an arsenal of strict control measures, in particular, the introduction of state decoupling audit of low-carbon production, which will ensure the formation according to the decoupling approach of the most realistic portfolio of the state of transition of a particular industry to low-carbon production.

The author's economic and mathematical models of estimation according to the decoupling approach of the influence of crop and livestock industries on atmospheric pollution are offered. A comparative analysis of forecasts of changes in GHG emissions with increasing gross output of agricultural production, defined by the Institute of Economics and Forecasting of the NAS of Ukraine in different scenarios of economic development with forecasts determined by



the author's method and identified by the results of GAP-analysis ways to achieve the ambitious goals set by the Low Carbon Development Strategy of Ukraine until 2050.

The expediency of supplementing the GRI 300 "Environmental Disclosures" (The Global Reporting Initiative 300, 2017) in the framework of the preparation of the second National Determined Contribution to the Paris Agreement has been substantiated. They are currently in the process of adapting a set of indicators to the GRI-305.5 "Reduction of GHG emissions", which will ensure compliance with the commitments made by each of the enterprises to implement the transition to low-carbon production.

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