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REGIONAL DIFFERENCES OF GREENHOUSE GASES FROM AGRICULTURAL ACTIVITIES IN BULGARIA

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Abstract
The leading role in the implementation of environmental protection and climate change policies belongs to the European Union. In this regard, the European Green Pact includes measures aimed at reducing greenhouse gas emissions by 2030 and carbon emissions by 2050. Establishing trends and the intensity of ongoing processes are of particular importance in revealing differences in the development of regions, as well as the need to take adequate measures to reduce and limit them. In this sense, in the article, monitoring of greenhouse gas emissions from the implementation of agricultural activity was carried out. An analysis of the levels and rates of change in greenhouse gas emissions by individual components of Bulgaria's agriculture was carried out for the period 2018 – 2022. In addition, a comparative analysis was made compared to 1990 and compared to 2007. The positioning of the individual regions in Bulgaria regarding the reduction or increase in emissions. The main goal of the study is to analyze the main indicators – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) for the statistical regions in Bulgaria (North – West, North – Central, North – East, South – East, South – West and South – Central planning regions), regarding the current picture of the state and trends in the levels of greenhouse gas emissions from the activity of economic units in the agrarian sector. The analysis of the dynamics regarding the levels of CO_2, CH_4 and N_2O shows that for all six studied regions a significant decrease in values in 2007 compared to the base year 1990 is characteristic. The percentage decrease is greatest for the North-Central and North-East region (–83.48), followed by the North – West (–57.95). The reduction of methane emissions is more than 60% in different regions, and for N_2O it is in the range of –58.99 to –62.03. For the period 2018 – 2022, an increasing trend of the CO_2 and N_2O indicator is established compared to both the base year 1990 and 2007 in all studied statistical regions. For the same 5-year period, different trends are observed in the methane emissions in the individual studied areas. For three of them NWPR, SEPR and the SCPR, a sustainable reduction in emissions is observed. Despite the decrease in emissions in 2007, for the rest of the 5-year period, an increase is reported for the NCPR and NEPR, especially for the last 3 years. The South – West region is characterized by a decrease that continues until 2019, and for the remaining 3 years emissions increase again.
Keywords: agriculture, greenhouse gas emissions, planning areas, analysis
JEL code: O18, Q54, Q01

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Introduction

As an important share of the Bulgarian economy, agriculture is a highly vulnerable sector under the influence of climate change, especially in the cultivation of cereals, technical crops, fruits and vegetables. At the same time, innovative farmers are the ones who must constantly adapt to the constantly developing market, institutional and natural environment, in order to increase their agrarian sustainability. At the same time, the risk of the impact of climate change is not evenly distributed territorially. Individual regions differ in the likelihood of negative consequences, and the presence of inequalities within and between these regions is a signal of placing the emphasis both on the state regional policy and on rural development programs, on overcoming of fluctuations as a significant problem and a negative factor impact on regional development (Kotsev, 2021).

Agriculture is not only a strategic and priority sector for the development of the Bulgarian economy, but it is even much more than what is meant in the economic sense. This sector is essential for human society and plays an important role in the transition to sustainability. Agricultural activity has a direct and indirect impact on the protection and preservation of the environment, the purity of food and rural communities. It is for this reason that we should not consider agriculture solely as an economic sector, but as a sector with multifaceted benefits.

The rethinking of traditional agricultural practices, through agroecology, changing dietary habits, etc., can offer effective solutions and multiple benefits. For example, agro-ecological practices, sustainable production models, integrated production, regenerative agriculture, etc. they can certainly increase the resilience not only of individual economic units, but also of sensitive rural areas (Kirechev, 2017), (EU, 2020), (Nikolova M., 2013), (Nikolova M., 2022) etc. At the same time, this can reduce pressure on the environment and contribute to reducing greenhouse gas emissions (Billen, et al., 2021). After Bulgaria's EU membership (2007), the focus gradually shifted from agricultural productivity to a greater emphasis on environmental issues, through regulations and economic incentives.

The National Climate Change Adaptation Strategy and Action Plan of the Republic of Bulgaria defines the framework for climate change adaptation (CCA) actions and priority directions until 2030, identifying and confirming the need for CCA actions for the entire economy, as well as at the sector level incl. the agricultural sector (Dale, Zhekova, Ambrosi, Milova, & Bakx, 2018). Climate change mitigation and adaptation policy is linked to the two main strategies – mitigation and adaptation. The mitigation strategy (Ministry of environment and water, 2020) emphasizes the reduction of the anthropogenic impact on the amount of greenhouse gases or their removal from the atmosphere. Adaptation strategy is related to adaptation to current or expected climate changes and their consequences (Ministry of environment and water, 2018). Due to the need for timely measures and working solutions for each country, the issue of achieving a harmonious and balanced balance between economic progress and environmental protection becomes a priority. Agrarian business, as part of transformations in the economic environment, is

also responsible to a significant extent for minimizing or removing greenhouse gases from the atmosphere. In the long-term climate change mitigation strategy until 2050 of the Republic of Bulgaria, the following two main goals have been identified:

- ❖ OBJECTIVE 1: reduction and/or optimization of emissions in the agricultural sector;
- ❖ OBJECTIVE 2: increase the awareness of both farmers and administration about the impact of their actions on climate change. The priorities for achieving the described goals are in the following areas:
  - ✓ reducing emissions from agricultural land;
  - ✓ reducing methane emissions from organic fermentation in animal husbandry;
  - ✓ improving manure management;
  - ✓ optimizing the use of plant residues in agriculture;
  - ✓ improving rice field management and rice production technologies;
  - ✓ improving farmers' and administration's knowledge about reducing emissions from the agricultural sector.

Due to the topicality of the problems in recent years, a number of authors have worked on issues related to the state and trends of greenhouse gases from agriculture. In most of the scientific publications, the issue is considered complex, i.e. Agriculture and animal husbandry are jointly analyzed as sources of greenhouse gases (Nenova, 2017). The complex approach is necessary due to the presence of various problems (Nenova, 2015): obtaining results from the application of environmentally friendly practices in plant breeding, corresponding to the reduction of global warming, requires a long period of time, in animal breeding there are processes that emit greenhouse gases that are not part of from the official statistics for the sub-sector, etc. The same author suggests that certain limits should be introduced during the monitoring in which the emissions from the respective sources can vary (e.g. from a unit of area or one head of animal), so that deviations can be observed (Nenova, 2015). In this publication, we pay attention to the generated greenhouse gas emissions from the activity of agricultural units at the NUTS2 level – by planning regions.

The aim of the present study is a comparative analysis of the state and trends of greenhouse gas emissions related to agricultural activity at the level of statistical regions.

Methodology

The object of research is **greenhouse gas emissions**, expressed in kton CO_2eq, using the values of the global warming potential (GWP-100) from IPCC AR5 (Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5). Values for major gas components – Fossil CO_2, CH_4 and N_2O from the Long-Term Emissions Database for Global Atmospheric Research – (EDGAR, 2023) (Crippa, Guizzardi, Pagani, & Pisoni, 2023). Data have been selected from the agricultural sector (in another author's publication, other economic sectors are also considered) for the statistical regions in Bulgaria. The analysis of the data is carried out by comparing

the changes in the values with a reference year – 1990 (available database) and 2007 (Bulgaria – member of the EU), as well as the period 2018 – 2022 (for 2022 is the last statistical information available).
The tasks set by the authors are:

- Tracking the dynamics and structure of atmospheric air pollutant emissions by species, by applying methods of dynamic series analysis and analysis and assessment of structural changes;
- Analyzing the structural changes of greenhouse gas emissions with ranking by species and by planning areas.

For the purpose of the analysis, official statistics were used of European Union 2023, European Commission, Joint Research Center (JRC), EDGAR (Emissions Database for Global Atmospheric Research) Community Greenhouse Gas Database including IEA-EDGAR CO_2, EDGAR CH_4, EDGAR N_2O (2023).

Results

The 2021 Special Audit Report (European Court of Auditors, 2021) on the Common Agricultural Policy (CAP) and climate noted that half of the EU's climate action funds are spent through the CAP, but emissions from agriculture are not falling. The same report presents three main recommendations:

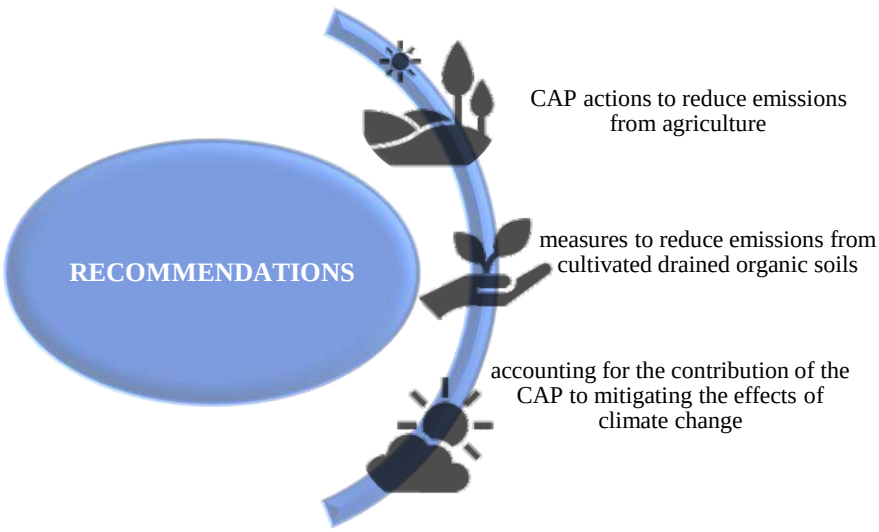

Figure 1. Main recommendations of the European Court of Auditors for the reduction of greenhouse gas emissions in the development of agricultural activity

The first recommendation is related to the role of the European Commission in establishing the objective of reducing greenhouse emissions from agricultural activity

in the territory of each European country, evaluating the CAP strategic plans and presenting incentives to reduce greenhouse gas emissions. The second recommendation to reduce emissions from cultivated drained organic soils is related to the measures to introduce a monitoring system in impact assessment after 2020 on peatlands and wetlands and direct payments for rural development and other CO_2 sequestration measures with a deadline for implementation – September 2024. The third recommendation for accounting for the contribution of the CAP to mitigating the consequences of climate change until 2030 is aimed at systematizing important monitoring indicators regarding the impact of the CAP for the period 2021 – 2027 of the measures taken to climate change mitigation on net greenhouse emissions. Also, this recommendation is related to applying the "polluter pays" rule on emissions from agricultural activities and incentivizing farmers to absorb carbon in the long term. The implementation of the first and third recommendations is until December last year. In principle, Bulgaria fulfills a general goal of reducing greenhouse gas emissions by at least 40% by 2030 (Ministry of environment and water, 2024).

In connection with the implementation of the given recommendations, the aspiration of each country is increasing, incl. Bulgaria for taking specific decisions and initiatives in the problem area. For example, at the AGRA-2024 exhibition, the Bulgarian company INOVEX Group presented the possibilities of carbon farming, through the participation of agricultural producers in a soil carbon certification program[1]. (INOVEX). At the end of July this year, the light projection "Horizon" of the National Palace of Culture, Sofia visualized messages about climate change, the important role of science in finding solutions and the personal responsibility of people[2]. At the same time, state institutions, non-governmental organizations and in a number of Bulgarian educational institutions are conducting initiatives in relation to climate change and possible solutions for mitigating the consequences.

From an audit report on the inventories of greenhouse gases in the EU-27 for the period 1990 – 2018 it is clear that in the period 1990 – 2010 they decreased by 25% mainly due to the decrease in the use of fertilizers and in the number of farm animals, with the largest decrease in the period 1990 – 1994. After 2010, emissions did not decrease more (European Court of Auditors, 2021).

[1] INOVEX Group is in partnership with the company Agreena (Denmark). Agreena Carbon is the world's largest soil carbon certification program accredited to monitor, quantify, validate and verify carbon sequestration and emission reductions.

[2] Bulgaria and MoEW are hosting the 61st plenary session of the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change, IPCC) in Sofia under the Horizon 2024 project. By August 2, nearly 500 delegates from the panel's 150 member states discussed issues related to the organization's reporting during the Seventh Review Cycle, which begins in July 2023.

For the purpose of the analysis regarding the ecological status of the studied regions, the greenhouse gas emissions expressed in kton CO_2 were considered, using the values of the global warming potential (GWP – 100) from the IPCC AR5 (Intergovernmental Panel on Climate Change, 2014). In this case, we analyze data for main gas components – Fossil CO_2, N_2O, CH_4, AR5[1]. Carbon dioxide emissions on the territory of a country are an important indicator and they have the largest share of greenhouse gases contributing to global warming and climate change. For greater completeness, when assessing the impact on climate change in our country, gases such as methane and nitrous oxide are also analyzed.

From the Long-Year Emission Data Base for Global Atmospheric Research – EDGAR (EDGAR, 2023) and (Crippa, Guizzardi, Pagani, & Pisoni, 2023) the data with 3 main components in the sector – agriculture have been selected (in another author's publication other economic sectors are also considered) for all statistical regions in Bulgaria. The changes in values compared to 1990, which was accepted as a reference year in terms of the level of emissions, 2007 (Bulgaria was accepted as a member of the EU) and the last 5-year period 2018 – 2022 of the available data were tracked from the available statistical information.

Table 1 presents the data on the level of *CO_2 emissions* in 1990 (reference year), 2007 (the year of our membership in the EU) and the last five years of available statistical data.

The analysis of the dynamics in relation to the level of CO_2 shows that all six regions are characterized by a significant decrease in values in 2007, compared to the base year 1990. The percentage decrease is greatest in the North – Central and North – Eastern regions (–83,48), and the second place with the same trend is occupied by the Northwest (–57.95). The reduction of emissions for this component is within the limits of –36.1 to –45.3 for the remaining 3 southern regions, with the lowest degree being in the South-West region. It is noteworthy that for the period 2018 – 2022 there is a trend for a steady increase in the indicator compared to both the baseline and the year in which Bulgaria joined the EU member states (2007).

[1] Global warming potentials measure: how much energy shall the emissions of one ton of a gas absorb over a period of time, corresponding to the emissions of one ton of carbon dioxide (CO_2). Microsoft Sustainability Manager allows selection between Intergovernmental Panel on Climate Change (IPCC) Assessment Reports 4, 5 and 6, each with a 100-year time horizon.

Table 1. Dynamics of CO2 greenhouse gas emissions from agricultural activity by planning areas

STATISTICAL REGIONS	YEARS						
Fossil CO_2_AR5	**1990**	**2007**	**2018**	**2019**	**2020**	**2021**	**2022**
NWPR	61,36	25,80	62,04	69,56	74,83	86,29	89,12
NCPR	26,88	4,44	23,68	27,00	29,04	32,00	35,27
NEPR	30,63	5,06	26,98	30,76	33,09	36,47	40,20
SEPR	125,85	68,84	135,34	150,72	162,15	190,41	191,51
SWPR	352,79	225,43	395,94	438,94	472,25	561,19	554,68
SCPR	104,92	58,57	113,44	126,25	135,83	159,75	160,31

Source: https://edgar.jrc.ec.europa.eu/dataset_ghg80_nuts2 and own calculations

The following table (table 2) shows the data regarding greenhouse gas emissions from *CH_4 methane*. The emission reductions in 2007 in percentage terms are over 60% for both the northern and southern regions in the range of –63.5% to –66.7%, compared to the base year – 1990.

Table 2. Dynamics of CH4 emissions from agricultural activity by planning areas

STATISTICAL REGIONS	YEARS							
CH_4_AR5	**1990**	**2007**	**% of change**	**2018**	**2019**	**2020**	**2021**	**2022**
NWPR	837.03	301.01	–64.04	268.75	258.46	282.19	286.56	289.10
NCPR	1016.04	363.91	–64.18	387.87	374.33	410.24	415.77	419.98
NEPR	949.80	329.62	–65.30	503.53	485.92	533.16	540.26	545.82
SEPR	2578.52	941.18	–63.50	440.99	425.10	464.35	469.78	474.04
SWPR	532.69	178.11	–66.56	139.11	135.42	144.92	146.41	147.46
SCPR	1371.02	456.57	–66.70	343.88	335.21	359.26	361.38	362.41

Source: https://edgar.jrc.ec.europa.eu/dataset_ghg80_nuts2 and own calculations

The analysis for the period 2018 – 2022 shows divergent trends in the individual studied regions. For three of them, NWPR, SEPR and SCPR, a sustainable reduction in emissions is observed not only compared to the baseline, but also compared to 2007. After 2019, a slight increase is reported for NWPR, compared to the previous two years, while for SEPR and SCPR there is a characteristic increase of the

values for the last three years of the research period. Despite the decrease in emissions in 2007, for the rest of the 5-year period, an increase is reported for the NCPR and NEPR, especially for the last 3 years. The South-West region is characterized by a decrease that continues until 2019, and for the remaining 3 years the emissions increase again in the range from 144.92 to 147.46.
The dynamics of *nitrous oxide* by planning areas is presented in the table. 3. Here again, the percentage change in emissions is positive, i.e. a significant decrease in 2007 compared to the reference year 1990 (in the range of –58.99 to –62.03).

Table 3. Dynamics of greenhouse gas emissions N2O from agricultural activity by planning areas

STATISTICAL REGIONS	**YEARS**							
N2O _AR5	**1990**	**2007**	**% of change**	**2018**	**2019**	**2020**	**2021**	**2022**
NWPR	794.64	325.89	–58.99	589.55	607.01	625.62	663.68	662.14
NCPR	738.61	299.67	–59.43	544.48	560.09	577.31	612.70	610.94
NEPR	799.11	326.37	–59.16	615.77	633.25	650.96	693.45	690.26
SEPR	923.11	356.66	–61.36	554.90	568.10	590.18	626.36	626.77
SWPR	385.54	148.75	–61.42	230.43	234.24	245.03	258.06	259.94
SCPR	744.48	282.32	–62.03	452.08	459.34	477.74	505.24	506.68

Source: https://edgar.jrc.ec.europa.eu/dataset_ghg80_nuts2 and own calculations

However, for the period 2018 – 2022, a continuous increase in values is characteristic of all studied statistical regions.
Based on the calculated value indicators for the rates of change in the studied regions, a ranking was made for the agriculture sector for three of the components – carbon dioxide, methane and nitrous oxide (CO_2, CH_4 and N_2O).
On the table 4, we have presented the change in *the carbon dioxide* content for the last year of the study period – 2022. The calculations were performed based on the reference year 1990 and the second time – the year Bulgaria became a member of the EU (2007) for greater clarity of the changes that have occurred. Rank one is given to the region with the greatest reduction in harmful emissions, respectively rank 6 to the sector with the greatest increase. The trend of increasing CO_2 values on a national scale is alarming, i.e. on the territory of all studied areas. From the table it is clear that for the component – carbon dioxide, the agriculture sector is with the largest increase in greenhouse gases for the Northwest region (289.10% – rank 6, compared to 1990), while for the North Central region and the Northeast, the percentage change towards increasing gases is more than 9 times lower (31.24 – rank 1).

Table 4. Rate of change of greenhouse gas emissions – Fossil CO_2 and ranking by planning areas

STATISTICAL REGIONS	2022	Change from 1990	Change from 2007	Rank 1990	Rank 2007
NWPR	89.12	**289.10**	245.43	6	4
NCPR	35,27	**31.24**	**694.42**	1	6
NEPR	40.20	**31.24**	**694.42**	1	6
SEPR	191.51	52.18	178.22	2	3
SWPR	554.68	57.22	**146.05**	4	1
SCPR	160,31	52.79	173.72	3	2

Source: https://edgar.jrc.ec.europa.eu/dataset_ghg80_nuts2 and own calculations

When tracking the change from the 2007 base year, the trend reverses, with the North Central and Northeast regions repositioning in the rankings from first to sixth (694.42). The South West region has the lowest values at 146.05 or rank 1.
The rate of change of *methane emissions* and the ranking by planning areas is shown in the table. 5. Unlike carbon dioxide, the change here is unidirectional both compared to the base year 1990 and also compared to 2007.

Table 5. Rate of change of greenhouse gas emissions – CH_4 and ranking by planning areas

STATISTICALLY REGIONS	2022	Amendment compared to 1990	Amendment compared to 2007	Rank 1990	Rank 2007
NWPR	289.10	–65.46	–3.96	4	4
NCPR	419.98	–58.67	15.41	5	5
NEPR	545.82	**–42.53**	**65.59**	6	6
SEPR	474.04	**–81.62**	–49.63	1	1
SWPR	147.46	–72.32	–17.21	3	3
SCPR	362.41	–73.57	–20.62	2	2

Source: https://edgar.jrc.ec.europa.eu/dataset_ghg80_nuts2 and own calculations

The regional differences when comparing the values in 2022 compared to 1990 are in the positive direction, i.e. reduction in each of the 6 planning areas. In this sense, the decrease in methane emissions is greatest in the Southeast region (–81.62) or rank 1, and least in the Northeast (–42.53). The same trend in terms of ranking applies when compared to the base year 2007, but the difference is in the North East region and the North Central region, where the values increase (65.59 and 15.41).

However, it is striking that the ranking from 1st to 6th rank remains identical in all the studied regions, i.e. in the sequence presented in the table.
The analysis of the data from tab. 6 for the *nitrogen dioxide component* show a decrease in greenhouse gas emissions compared to 1990 in both the northern and southern regions, i.e. on the entire Bulgarian territory. The positive trend is most pronounced in the South-West region (rank 1, –32.58) and weakest in the North-East (rank 6, –13.62). Unfortunately, however, the change compared to 2007 is negative in the direction of an increase in greenhouse gas emissions – N_2O, with the South – West planning region in first place and the North – East planning region in sixth place.

Table 6. Rate of change of greenhouse gas emissions – N_2O and ranking by planning areas

STATISTICALLY DISTRICTS	2022	Amendment compared to 1990	Amendment compared to 2007	Rank 1990	Rank 2007
NWPR	662.14	–16.67	103.18	5	4
NCPR	610.94	–17.28	103.87	4	5
NEPR	690.26	**–13.62**	**111.50**	6	6
SEPR	626.77	–32.10	75.73	3	2
SWPR	259.94	**–32.58**	**74,75**	1	1
SCPR	506.68	–31.94	79.47	2	3

Source: https://edgar.jrc.ec.europa.eu/dataset_ghg80_nuts2 and own calculations

The analysis of the data used and the author's calculations confirm the need for urgent and adequate solutions to adapt the agricultural sector to alternative and sustainable production processes that can reduce the ecological footprint of the business units. Despite the efforts made by the state institutions, this issue is on the agenda and requires timely and innovative solutions in the transforming economic environment towards sustainability. In this regard, the role and contribution of agrarian business to the achievement of the climate goals is increasingly growing and will continue to grow in the future.

Conclusion

1. A steady trend towards decreasing CO_2 values from agricultural activity in 2007 compared to the base year 1990 was found in the six planning areas. The most sensitive is the decrease for the North-Central and North-East regions (–83.48), followed by the North – West (–57.95). The decrease was the lowest in the Southwest region (–36.1). The trend of increasing carbon dioxide for the period 2018 – 2022 compared to both the base year 1990 and the year Bulgaria became

a member of the EU (2007) is alarming. An increase is reported in the NCPR and SEPR, especially for the last 3 years. In the Southwest region, a positive downward trend is observed until 2019, while for the remaining 3 years emissions increase again within the range from 144.92 to 147.46.

2. Methane emissions from the activity of the agricultural sector in 2007 were reduced by more than 60% for both the northern and southern regions in the range of –63.5% to –66.7%, compared to the base year – 1990. For the period 2018 – 2022, a two-way trend is observed – a decrease or an increase in the studied areas. Despite the decrease in emissions in 2007, for the studied 5-year period, an increase is reported for the NCPR and NEPR, especially for the last 3 years. For the Southwest region, the reduction continues until 2019, and for the remaining 3 years emissions increase again.
3. The dynamics of nitrous oxide in the agricultural sector by planning regions is characterized by a significant decrease in 2007 (in the range from –58.99 to –62.03). However, in all the studied statistical regions, a negative trend of continuous increase in values is reported for the 5-year period (2018 – 2022).
4. The ranking of the studied areas under the CO_2 component depending on the rates of change of harmful emissions from the activity of the agricultural sector in 2022 compared to 1990 and 2007 shows that the North Central and North Eastern regions are repositioning from first to sixth rank (694.42), while the Southwest region has the lowest values –146.05 or rank 1.
5. The trend in terms of the rate of change of methane emissions in 2022 compared to 1990 and also compared to 2007 is positive. The reduction of methane emissions is the largest in the South-East region (–81.62) – rank 1, and the least in the North-East (–42.53). When compared to the base year 2007, negative regional differences are observed in the Northeast and North Central regions, where the values increase (65.59 and 15.41). The sequence of positioning from the 1st to the 6th rank is kept identical for all the studied areas in both cases.
6. For the northern and southern regions of Bulgaria in 2022, a decrease in greenhouse gas emissions for the nitrogen dioxide component was found compared to 1990, but the change compared to 2007 is negative in the direction of an increase in greenhouse gas emissions – Southwest (rank 1) and the Northeast Planning Region (rank 6).

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References

Billen, G., Aguilera, E., Einarsson, R., Garnier, J., Gingrich, S., Grizzetti, . . . Cobena, A. (2021). Reshaping the European agro-food system and closing its nitrogen cycle: The potential of combining dietary change, agroecology, and circularity. *One Earth, 4*(6), 839-850. doi:https://doi.org/10.1016/j.oneear.2021.05.008

Crippa, M., Guizzardi, D., Pagani, F., & Pisoni, E. (2023). *GHG emissions at sub-national level (v2.0). European Commission, Joint Research Centre (JRC).*

doi:10.2905/ D67EEDA8-C03E-4421-95D0-0ADC460B9658

Dale, N., Zhekova, S., Ambrosi, P., Milova, E., & Bakx, R. (2018). *National Climate Change Adaptation Strategy and Action Plan.* Retrieved from https://www.moew.government.bg/static/media/ups/articles/attachments/Strategy%20and%20Action%20Plan%20-%20Full%20Report%20-BGcd6d12eb7bc7294e29ac9ee4762fd2d8.pdf

EDGAR. (2023). Retrieved from https://edgar.jrc.ec.europa.eu/dataset_ghg80_nuts2

EU. (2020). *Biodiversity strategy for 2030*. Retrieved 2024, from https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_bg

European Court of Auditors. (2021). *Special Report 16 Common Agricultural Policy and climate.* Retrieved from https://www.eca.europa.eu/bg/publications?did=58913

INOVEX. (n.d.). *Carbon certificates with no cost for farmers from Agreena and INOVEX Group*. Retrieved 2024, from https://inovex.bg/bg/News/News/Carbon_certificates_with_no_cost_for_farmers_from_Agreena_and_INOVEX_Group/598

Intergovernmental Panel on Climate Change. (2014). *Assessment Report 5*.

Kirechev, D. (2017). Impact of Climate Change on the Development of the Agrarian Sector – Adaptation and Mitigation Measures. *Izvestia, Journal of the Union of Scientists – Varna 1/2017*, pp. 111 – 125.

Kotsev, R. (2021). Fluctuations of the development of rural areas in Bulgaria. *Abstract of a Dissertation Work*, 3.

Krasteva, I. (2017). Possibilities and prospects for the development of organic production in Bulgaria. *Eastern Academic Journal, бр.4*, pp. 41 – 51.

Ministry of environment and water. (2018). *National Climate Change Adaptation Strategy and Action Plan of Republic Bulgaria.*

Ministry of environment and water. (2020). *Long-term strategy for the mitigation of climate change until 2050 for the republic of Bulgaria.* Retrieved from https://www.moew.government.bg/static/media/ups/articles/attachments/BG%20LTS%202050573839cd4d01854ef8b597881fde2256.pdf

Ministry of environment and water. (2024). *Climate*. Retrieved from https://www.moew.government.bg/bg/klimat/

Nenova, R. (2015). Monitoring of Agricultural Greenhouse Gas Emissions. *Economic Archive, 4*(4), 88.

Nenova, R. (2017). *The climate state and trends in Bulgaria and greenhouse gas emissions from agriculture.* Академично издателство "Ценов".

Nikolova, M. (2022). *Sustainable development of agriculture – modern aspects and sustainable models.* Sofia: Valdes VV-GV.

Nikolova, M. (2013). Challenges to organic agriculture in Bulgaria. *Ekonomske teme, 1, Економски факултет Ниш*, 195.

Yordanova, E. (2023). Problems, trends and characteristics in the development of modern agriculture in Bulgaria. *Eastern Academic Journal, бр.1*, pp. 55 – 61.