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HANNA PONDEL

Poznań University of Economics and Business

AGRICULTURE IN THE FACE OF CLIMATE CHALLENGES – THE PROBLEM OF GREENHOUSE GAS EMISSIONS

Key words: agriculture, climate change, greenhouse gas emission, sustainable development

ABSTRACT. Changes in seasonal weather cycles, a growing number of extreme phenomena, an upward trend in temperature and changes in the distribution of rainfall, significantly affect the functioning and effectiveness of agriculture. However, agriculture plays a major role in the emergence and intensification of these phenomena. The aim of the article is to present, analyse and evaluate the relations between agriculture and climate, with particular emphasis on greenhouse gas (GHG) emissions from agriculture in these relations. A cause-and-effect analysis was conducted based on literature studies, using the descriptive statistics method and analysis of the development trend. The basis for analysis were data on GHG emissions in the European Union (EU-28). The contribution of agriculture to the EU's greenhouse gas emissions, albeit slightly but still increasing in recent years. The level of this emission is determined primarily by the type of agricultural activity conducted – animal production is definitely responsible for higher emissions than plant production. It is difficult to present a universal model of agricultural adaptation to climate change and a set of actions limiting the negative impact of agricultural production on climate. This is hindered by both the specificity of the agricultural sector and the large diversity of local conditions and applied farming practices. The opportunity to increase the effectiveness of actions taken may be a better connection between the implementation of objectives including the reduction of the causes and negative consequences of climate change and the objectives of sustainable agricultural development.

INTRODUCTION

Changes in seasonal weather cycles, a growing number of extreme phenomena (drought, floods, storms, hurricanes), an upward trend in temperature, or changes in the distribution of rainfall, significantly affect the functioning and effectiveness of agriculture. It should be remembered, however, that it is precisely agriculture that is playing a major role in the emergence of these phenomena. The agriculture-climate relations have a feedback nature: agriculture, through its activity, strongly influences climate change, while climate change strongly determines agricultural activity. Potential threats become particularly important due to the global scale of the phenomena mentioned above, affecting, with varying intensity and in various forms, the agriculture of the whole world, constituting a strategic sector for the food safety of the inhabitants of Earth.

Sustainable agricultural production, rationally using environmental resources, is essential for the preservation of basic ecosystem services. Modern, adapted to the changing

environmental conditions, system solutions covering the functioning of the agricultural sector are required, offered, among others, under the common agricultural policy. Although this policy has evolved to become "greener", it still supports intensive agriculture in the first place, accepting its increased pressure on the environment. The current agricultural policy mainly takes into account the economic aspect of agricultural activity, paying less attention to social and environmental needs. Meanwhile, the problems arising at the interface between agriculture and climate should definitely be considered in all three dimensions of sustainable development.

The aim of the article is to present, analyse and evaluate the relations between agriculture and climate, with particular emphasis on greenhouse gas emissions from agriculture in these relations. Due to the gravity of the issue, taking into account feedback in agriculture-climate relations, the article focuses primarily on the impact of agriculture on climate change. The paper is based on secondary sources of information and results of previous research on the subject matter in both – national and global terms.

RESEARCH MATERIAL AND METHODOLOGY

The article contains the cause-and-effect analysis concerning the agriculture-climate relation, based on literature studies, using the descriptive statistics method and analysis of the development trend. The basis for the analysis were data on greenhouse gas emissions in the European Union (EU-28), for the years 2007-2016.

The trend was estimated in terms of greenhouse gas emissions from agriculture. The least squares method was used in the paper, assuming that the trend is a linear function ($y = a\ bt$)[1]. Parameters of the trend function were determined based on the following formulas:

$$a = \frac{\sum y - b\sum t}{N}$$

$$b = \frac{N\sum yt - \sum y\sum t}{N\sum t^2 - (\sum t)^2}$$

where: a, b – function parameters; y – empirical values of the phenomenon (real); t – numbers of periods; N – number of analysed periods [Mruk 2003].

Evaluations of trend adaptation to empirical values were made based on the following measures [Mruk 2003]:

a) convergence coefficient:

$$\varphi^2 = \frac{\sum(y - \hat{y})^2}{\sum(y - \bar{y})^2}$$

where: y – values of individual signs of the time series; $\hat{y}$ – theoretical values obtained from the trend function; $\bar{y}$ – the arithmetic mean of the empirical values of the variable;

[1] According to Henryk Mruk [2003], the vast majority of development processes are eligible to be represented by a straight line, and the linear function is the most commonly used model for analysing and forecasting the development of the phenomenon over time.

b) determination coefficient:

$$R^2 = 1 - \varphi^2$$

The output data for the trend analysis was obtained from the European statistics database – Eurostat. In the cause-and-effect analysis of the impact of agriculture on climate, the literature on the subject and reports of national and international institutions were also used.

IMPACT OF AGRICULTURE ON CLIMATE CHANGE

The main cause of climate change in the world is the emission of greenhouse gases (GHG) from human activities, which include, among others, agriculture. The emission of these gases is dominated by carbon dioxide (CO_2), but agricultural activity is mainly the source of: methane (CH_4) – its source is primarily animal intestinal fermentation and nitrous oxide (N_2O) – coming mainly from anaerobic digestion of faeces, nitrification and denitrification of organic nitrogen. The emission of these gases accounts for about 8 to 18% of total GHG emissions [Dorszewski et al. 2015]. In case of agricultural activity, GHG emissions also result from biological processes occurring on arable lands and permanent grasslands which include the cultivation of crops, organic and mineral fertilisation, the decomposition of crop residues and the burning of grass [Syp 2017].

The European Union is the third largest emitter of greenhouse gases in the world – after China and the United States. Four major emitters (China, the USA, the EU28 and India) have contributed to more than 56% of total greenhouse gas emissions over the last decade, excluding land-use change (LUC). Emission of the 7 largest emitters (including Russia, Japan and international transport) accounted for over 66 percent of total GHG emissions. In turn, G20 members contributed to 78% of total GHG emissions [UN Environment 2018]. European Union agriculture is responsible for nearly 10% of greenhouse gases emitted by the Community. Estimates indicate that 58% of this emission is N_2O, while 42% is CH_4 [Wieliczko 2016].

Agricultural contribution to EU's greenhouse gas emissions, albeit slightly but still increasing (Figure 1), is an important indication of the need to take action to reduce this phenomenon.

According to data from 2016, six EU countries with the highest GHG emissions from agriculture are: France, Germany, Great Britain, Spain, Italy and Poland. In the last three countries, this emission was at a level of 30-35 million tonnes per year, in France - more than twice as much [UN Environment 2018].

The level of greenhouse gas emissions in agriculture is determined primarily by the type of agricultural activity conducted – animal production is definitely responsible for higher emissions than plant production (Table 1).

Diversity in the amount of greenhouse gases polluting the air also occurs within the directions of production – in the case of animals, most methane is produced by cattle and sheep, much less by horses or pigs. The diversity of these amounts is also related to the age of the animal or the type of feed used. Natural fertilisers (e.g. manure) are a source of both – methane and nitrous oxide.

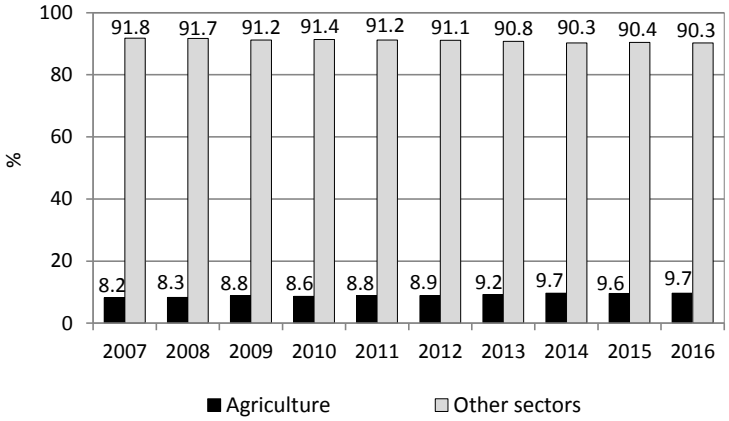

Figure 1. The contribution of agricultural emissions to total GHG emissions of the EU-28 in 2007-2016

Source: [UN Environment 2018]

Table 1. Data used to estimate the trend function of the level of greenhouse gas emissions from agriculture in the EU-28

Years (t)	Emission amount (in thousands tonnes)				
	agriculture in total (y_1)	livestock (y_2)	enteric fermentation (y_3)	manure management (y_4)	managed agricultural soils (y_5)
2007 - 1	432,714.30	262,595.66	192,970.26	69,625.40	155,494.93
2008 – 2	430,240.68	260,049.64	191,972.30	68,077.34	156,460.12
2009 – 3	424,796.39	258,281.37	190,383.81	67,897.56	152,239.65
2010 – 4	419,707.43	253,610.38	188,215.26	65,395.12	152,099.68
2011 – 5	420,177.78	251,618.50	186,259.42	65,359.07	153,940.31
2012 – 6	418,034.31	249,893.81	185,822.96	64,070.85	153,174.13
2013 – 7	421,283.56	249,941.79	186,787.18	63,154.61	156,338.57
2014 – 8	428,402.67	252,768.20	188,572.70	64,195.50	160,243.94
2015 – 9	429,518.17	255,073.01	190,306.24	64,766.77	159,014.45
2016 – 10	430,001.72	255,213.24	190,898.99	64,314.26	159,010.50

Source: [UN Environment 2018]

In the processes of agricultural use of soil, a particular environmental burden is fertilisation, which results in an increase in the level of N_2O emissions [Wieliczko 2016]. The development trend regarding the level of greenhouse gas emissions from various areas of agricultural activity is shown in Figure 2.

In the European Union, in the analysed period, the linear trend function does not exactly describe the evolution of the analysed phenomenon, and, as shown in Table 1

and Figure 2, the changes in GHG emission were quite different in particular years. As results from the determined coefficients of convergence and determination, the adaptation of the trend function to empirical data is not the best, and the function, in the case of particular analysed categories, explains the variability of the dependent variable in about 40%. A clearer linear downward trend can be observed in the case of greenhouse gas emissions from manure management processes. Also, in the case of other types of trend functions, it is difficult to speak of a very good adaptation. This means a high complexity of the phenomenon and a very diverse and multidirectional set of causes, due to which it is difficult to attempt forecasts for the future.

Manure management in the European Union, in 2016, accounted for 15% of total emission from agriculture, emissions related to intestinal fermentation accounted for 44.5% of total emission from agriculture, and agricultural use of soil was responsible for 37% of emission from agricultural activity (Table. 1).

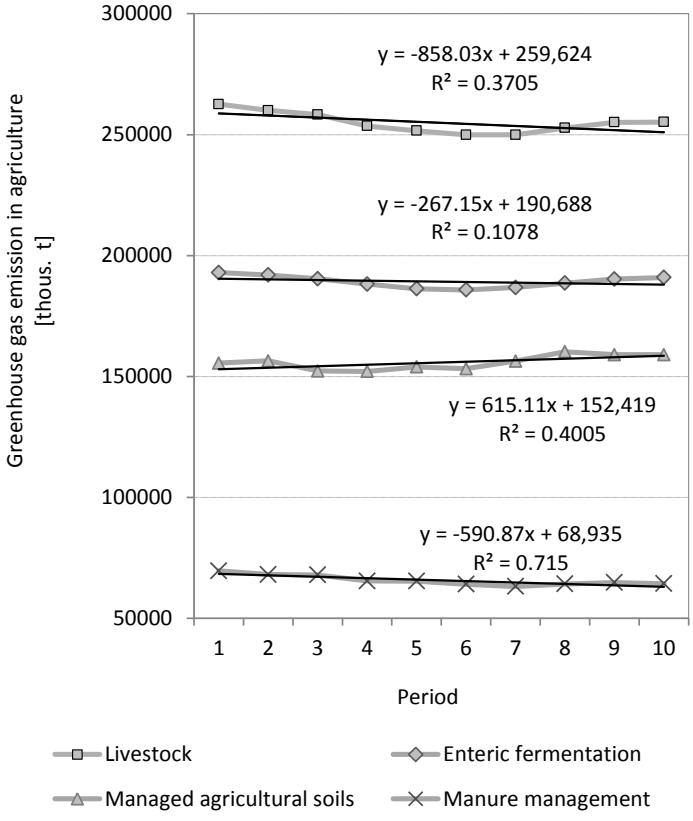

Figure 2. The development trend of GHG emissions from selected areas of agricultural activity in the EU-28

Source: own study based on Table 1

As can be noticed in Table 1, in the European Union, there was a small reduction in the amount of emissions from agriculture in the years 2007-2012, however, in the development of this amount there are visible fluctuations (as already mentioned, influencing the adaptation of the trend function) – primarily related to the size of the livestock population. The emission level reached its lowest value in 2012 – as a result of actions undertaken in the years 1990-2012, such as: reduction of livestock, more effective use of fertilisers and better management of manure (decrease of GHG emissions from agriculture by 24% in 1990-2012) [EEA 2015]. The growing global demand for food and the wealth of some developing countries have contributed to the upward trend in greenhouse gas emissions from agriculture after 2012.

Due to the role of food in human life, reduction of GHG emissions is extremely difficult. Since it is no longer possible to expect such large drops in livestock numbers as before, the following are necessary to limit the negative impact of animal production on climate: the modification of the production methods used, appropriate storage of natural fertilisers, the introduction of appropriate animal nutrition, the use of methane generated in animal production as an energy source in biogas plants [Witkowska-Dąbrowska 2018]. Changes in the consumption structure are also necessary, especially for meat and dairy products that have the largest global footprint in terms of CO_2 emissions and the consumption of raw materials and water per kilogram of food [EEA 2015].

In April 2018, the European Parliament adopted legislation to reduce carbon dioxide emissions by transport, agriculture, construction and waste sectors in the EU by at least 30% by 2030. The Parliament also adopted a separate project to reduce greenhouse gas emissions through usable land and forestry and increase the absorption of emissions by forests. EU countries have been obliged to implement the mechanisms that help in achieving a balance between CO_2 emissions and its absorption by forests, arable land and meadows [Osiński 2018]. An interesting project – Project 4‰, was presented by the French at the Conference of Parties to the United Nations Framework Convention on Climate Change (COP24). According to its authors, if the absorption of carbon in soil could be increased by 4‰ in agriculture, through appropriate cultivation, fertilisation, crop rotation, soil treatment, demineralisation, then anthropogenic carbon dioxide would be fully absorbed [COP24 2018].

DIMENSIONS OF THE AGRICULTURE-CLIMATE RELATIONS

The analysis of the cause-and-effect relations between agriculture and climate most often takes into account their environmental dimension. However, the economic dimension of these relations is increasingly emphasised, as evidenced, for example, by the estimated level of agricultural losses resulting from climate change.

The issue which is the subject of this study should undoubtedly be considered in a multidimensional way, i.e. including at least three basic dimensions of sustainable development - economic, social and environmental. Sustainable development is a concept of development that is strictly in line with the set of measures for adaptation to climate change taking place, especially sustainable agriculture. Table 2 attempts to determine what are or

Table 2. The economic, social and environmental dimension of the agriculture-climate relation considering their two-way nature

Dimension	Impact of agriculture on climate change	Impact of climate change for agriculture
ECONOMIC	– production losses in agriculture – lower effectiveness and profitability of production – irrational use of soil – lower quality of crops – insufficient supply of products – the need to build or modernise technical infrastructure adapted to new climate conditions – impoverishment of the populations of developing countries – expenditures necessary to reduce greenhouse gas emissions – costs related to the deteriorating health of societies – costs of implementing programmes and projects including innovative solutions	– variability of yield, plant and animal production efficiency – market destabilization – territorial shift of production – violent fluctuations in the prices of agri-food products – volatility of agricultural income – reduction in the expected value of income – changes in the import of products – the need to implement stabilization mechanisms for agricultural markets – concentration of the EU agricultural policy on support of risk management – problem with ensuring food security – threats to the product specialization of regions
SOCIAL	– deterioration of the quality of life – threat to human health – destruction of monuments and buildings – increasing the mobility of dangerous elements – the risk of land abandonment – transboundary transfer of pollutants – water shortage or excess – climate „refugee”	– disturbances in food supply – social unrest – change of product taste and quality – volatility of agricultural income – less people’s ability to work – territorial shift of production – abandonment of agricultural land – reducing the quality and availability of water resources – climate „refugee”
ENVIRONMENTAL	– air, soil and water pollution – global warming – acidification of soils, lakes, rivers – soil erosion – increased animal mortality – forest dieback and forest depletion – disturbances in the functioning of ecosystems – loss of biodiversity	– disturbances in the functioning of ecosystems – biodiversity threats – change of the village agricultural landscape – reducing the quality and availability of water resources – deterioration of soil quality – disturbances in the use of nutrients – pathogen increase

Source: own study

may be the consequences of changes in agriculture-climate relations taking into account various aspects of these changes. Because the relations between agriculture and climate are of feedback nature, the table also presents the effects of climate-agriculture impacts – such a look at the problem, undoubtedly gives a more complete picture of these consequences.

The scale of climate change effects, caused, among others, by agricultural activity, as well as effects on agriculture resulting from climate change, constitute an important premise for large-scale mitigation or prevention of climate change.

CONCLUSIONS

There is increasing evidence of the occurrence of global climate change. Agriculture is a sector of the economy that is, on the one hand, particularly dependent on climatic conditions and, on the other hand, strongly influences these conditions through its activities. The need to pay attention to agriculture-climate relations results mainly from possible global consequences of irregularities in these relations. Their consequences may be threats to food safety and the proper nutrition of societies. It is predicted that together with demographic development, an increase in real income for the population and changes in dietary habits, global demand for animal protein will increase in the future, and animal production will play a very important role in food supply. In view of the fact that the animal production department is most responsible for the level of greenhouse gas emissions, it is in this area, above all, that solutions should be found to limit the negative impact of agriculture on the climate.

The system of food production in conditions of climate change and competition for limited resources requires a coherent and integrated national, regional and global policy. This is reflected in the Directive on the reduction of national emissions of certain atmospheric pollutants for the years 2020-2030. It obliges European Union Member States (EU-28) to reduce ammonia emissions compared to 2005 by 6% each year in the period 2020-2029 and by 19% each year from 2030 [Directive EP 2016, Annex II, Table B]. Problems of climate change caused by greenhouse gas emissions and the issue of soil acidification are recognised in the European Union as crucial for the development of agriculture in the following years. This is reflected in planning, adopting strategic objectives, highlighting the role of sustainable agricultural development, as well as in shaping Common Agricultural Policy. The latter stresses the need to support farmers in their efforts to meet climate challenges, while taking into account the benefits for society as a whole.

It is difficult to present a universal model of adaptation of agriculture to climate change and a set of actions limiting the negative impact of agricultural production on the climate. This is hindered by both the specificity of the agricultural sector and the large diversity of local conditions and agricultural practices – both within the European Union and in individual countries. In each case, it seems that priority should be given to supplying agriculture with water and reducing water demand, raising farmer awareness of adaptation to climate change and developing specialised advice. It is necessary to search for solutions that would be cost-effective, accepted by farmers, and if possible, voluntary, flexible and not very complicated from an administrative point of view. The opportunity to increase

the effectiveness of actions taken may be a connection between the implementation of objectives including the reduction of the causes and consequences of climate change and the objectives of sustainable agricultural development, taking into account its dimensions.

It is undoubtedly important to remember that climate shocks have a negative impact not only on food producers but also on the situation of entire rural areas – deciding, among other things, on the quality of life of their inhabitants and the functioning of ecosystems.

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ROLNICTWO WOBEC WYZWAŃ KLIMATYCZNYCH – PROBLEM EMISJI GAZÓW CIEPLARNIANYCH

Słowa kluczowe: rolnictwo, zmiany klimatu, emisja gazów cieplarnianych, rozwój zrównoważony

ABSTRAKT

Zmiany sezonowych cyklów pogodowych, rosnąca liczba zjawisk ekstremalnych, wzrostowy trend temperaturowy i zmiany rozkładu opadów znacząco wpływają na funkcjonowanie i efektywność rolnictwa. Jednak to rolnictwo ma duży udział w powstawaniu i intensyfikacji tych zjawisk. Celem artykułu jest przedstawienie, analiza i ocena relacji rolnictwo – klimat, ze szczególnym uwzględnieniem w tych relacjach emisji gazów cieplarnianych z rolnictwa. Analizę przyczynowo-skutkową przeprowadzono na podstawie przeglądu literatury, z wykorzystaniem metody statystyki opisowej oraz analizy tendencji rozwojowej (trendu). Podstawę analiz stanowiły dane dotyczące emisji gazów cieplarnianych w Unii Europejskiej (UE-28). Udział rolnictwa w emisji gazów cieplarnianych UE, choć nieznacznie, ale jednak rośnie w ostatnich latach. O poziomie tej emisji decyduje przede wszystkim typ prowadzonej działalności rolniczej – produkcja zwierzęca zdecydowanie odpowiada za większe emisje niż produkcja roślinna. Trudno zaprezentować uniwersalny model adaptacji rolnictwa do zmian klimatycznych i zestaw działań ograniczających negatywne oddziaływanie produkcji rolnej na klimat. Utrudniają to zarówno specyfika sektora rolnego, jak i duże zróżnicowanie warunków lokalnych oraz stosowanych praktyk rolniczych. Szansą na zwiększenie efektywności podejmowanych działań, może być lepsze powiązanie realizacji celów obejmujących redukcję przyczyn i negatywnych konsekwencji zmian klimatycznych oraz celów zrównoważonego rozwoju rolnictwa.

AUTHOR

HANNA PONDEL, DR HAB. PROF. PUEB
ORCID: 0000-0002-0107-5552
Poznań University of Economics and Business
Department of Macroeconomics and Development Research
10 Niepodległości Av., 61-875 Poznań, Poland