EVALUATION OF THE ENVIRONMENTAL PERFORMANCE OF AGRICULTURAL PRODUCTION IN THE EUROPEAN UNION: SUSTAINABLE PRACTICES AND THEIR IMPACTS

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ABSTRACT

Agriculture is a major contributor to climate change, exerting significant pressure on environmental systems. The aim of this paper is to examine the relationship between the environmental performance of agricultural production and climate change in the European Union (EU) countries and to assess the degree of their homogeneity according to sustainability indicators. Correlation and cluster analyses were applied using data from the Environmental Performance Index (EPI). The results confirm a statistically significant positive correlation between agricultural performance and climate change mitigation, identifying three clusters of EU countries with different levels of environmental efficiency. The findings indicate that countries with higher agricultural sustainability achieve better results in reducing greenhouse gas emissions. The paper concludes that future agricultural policies within the European Union should promote sustainable production models that contribute to climate change mitigation while simultaneously enhancing the overall environmental performance of the agricultural sector.

Introduction

In the last few decades, environmental problems have become a global problem of humanity in terms of their existence and impact, as well as the socio-economic forces that produce them. The environmental problems that arise are closely related to the ever-

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increasing demand which comes from the increasing growth of the world population. Over the next 40 years, it is estimated that the demand for fresh water will increase by 50%, the demand for food by 70%, and the demand for energy will almost double (Naam, 2013). Most of the activities that man undertakes in order to satisfy the basic goals of life harm the living environment, leading to serious disturbances of the natural systems on the planet.

The overall development of human society in recent decades has led to increasingly unfavorable climate changes and a rise in the frequency of natural disasters. Climate change, biodiversity loss, and other environmental issues represent some of the greatest societal challenges of the 21st century. To address these challenges and guide society toward a sustainable future, it is essential to reduce greenhouse gas emissions and strengthen ecological resilience. Agriculture plays a crucial role in feeding the growing world population while simultaneously maintaining the delicate balance between production needs and environmental protection. However, agricultural activities are also a major source of greenhouse gas emissions and environmental degradation. Although numerous studies have examined the relationship between agriculture and the environment, the existing literature often lacks a comprehensive comparative analysis of the environmental performance of agricultural production across EU countries, particularly in the context of their contribution to climate change mitigation.

This paper seeks to fill that gap by analyzing the relationship between the environmental performance of agriculture and climate change in the European Union (EU) countries. Specifically, the study aims to group EU member states into homogeneous clusters according to their achieved level of environmental performance in agriculture and climate change mitigation. The analysis and discussion of results provide insights into the degree of ecological sustainability of agricultural production and its impact on climate change across EU countries.

Literature Review

Agriculture is an activity whose importance goes beyond the basic production of food,-and is of crutial importance for maintaining the general existence of the human population, which is experiencing constatnt growth. With regard to this, agriculture has influenced the transformation and increase in the sensitivity of ecosystems, but also the dependence and vulnerability of society on the environment (Milinčić et al., 2013). Agriculture uses about half of the global earth's surface and its existence and sustainability depend directly on the state of environment. Sunlight, water, nutrients and diversity of plants, animals and microbes play a fundamental role in agricultural production resulting in global food security (Ilić, 2022).

Human activities, in particular the emission of greenhouse gases, are the primary drivers of climate change (IPCC, 2023). Almost a decade has passed since the signing of the Paris Agreement on climate change, which envisages limiting global warming to 1.5 ºC in order to avoid a climate crisis, but the emission of greenhouse gases continues to grow (Ozdemir et al., 2023). Therefore, urgent action is needed to reverse this trend, given that the world may be approaching a dangerous tipping point in the climate system (Lenton et al., 2023).

The environmental impacts of the agricultural sector have been analyzed in numerous studies (Radivojević et al., 2019; Dabkiene et al., 2021; Wang et al., 2022; van Der Werf et al., 2020; Martin et al., 2023; Ncube et al., 2024) . Given the high degree of interdependence, agriculture can sustain or degrade the environment. Agriculture contributes to significant greenhouse gas emissions that cause climate change, 17% directly through agricultural activities and an additional 7 - 14% through land use change (OECD, 2016). In addition, the global emission of greenhouse gases is one of the environmental threats associated with food production, which contributes more than one quarter (26%) of emissions (Poore & Nemecek, 2018; Cui et al., 2024). The use of land in terms of changes caused by agriculture, which are harmful to the living environment, is reflected in the fact that about 44% of the inhabited land in the world is used precisely for agricultural production (Ritchie & Roser, 2024). Also, 70% of available drinking water globally is used for agriculture (FAO, 2011), while as much as 78% of freshwater and ocean pollution with nutrient-rich pollutants is caused by agricultural production (Poore & Nemecek, 2018). Agriculture is also considered responsible for major changes in biodiversity, where it is a threat to 24,000 species that are estimated to be at risk of extinction (Bar-On et al., 2018).

Due to the increasingly present biodiversity and climate crisis, caused by agricultural production that degrades the environment, meeting the growing demand for agricultural products will have to be done by maximizing the productivity of agricultural land (Pretty, 2018). For the sake of achieving higher productivity in agricultural production, the use of pesticides, which prevent crop loss and bring economic benefits to producers, is more and more common (Popp et al., 2013). This practice is accompanied by detrimental effect on the environment if used excessively (Larsen et al., 2017). The solution to the climate crisis requires a transition from the conventional model of production to alternative models which respect the natural limits of agricultural development at the expense of the environment (Żukowska et al., 2016). The contribution of agriculture to greenhouse gas emissions varies considerably as a result of differences in agricultural practices, as well as diverse natural and climatic conditions, including soil characteristics and temperature regimes. The mitigation of greenhouse gas emissions can be facilitated through a reduction in the demand for emission-intensive food products and the adoption of environmentally responsible agricultural production and land-management practices (Springmann, et al., 2018; Krstič, 2024). The application of renewable energy sources and the achievement of a higher level of energy efficiency can be a generator of future reductions in total greenhouse gas emissions. The COP 28 report recognized significant progress in terms of ending the use of fossil fuels, increased investments in solar energy, greater competitiveness of renewable energy sources, green construction and the application of agricultural innovations. Additionally, the rise in global awareness of climate change and willingness to reduce greenhouse gas emissions has never been greater (IEA, 2023).

The agricultural sector of the European Union contributes about 10% to the total emission of greenhouse gases (EC, 2019; EC, 2023.). Although agriculture is one of the sectors at the European Union level that has a small share of total greenhouse gas emissions, it contains “hidden emissions” attributed to other sectors, such as carbon dioxide emissions from fossil fuels and electricity that are used for agricultural machinery, crop drying and fertilizer production related to the energy sector (Paloviita & Järvelä, 2015).

Good progress was made in reducing emissions between 1990 and 2017, during which time greenhouse gas emissions from agriculture were reduced by around 20% (EC, 2021), contributing to the achievement of the European Union’s 2020 target. Furthermore, over the period from 2005 to 2022, the European Union achieved a reduction of approximately 5% in greenhouse gas emissions originating from the agricultural sector. At the same time, a further 2% reduction in these emissions is projected between 2022 and 2023 (EEA,2024). The European Union is making great efforts to reduce greenhouse gas emissions from agriculture, but on the other hand, it is trying to adapt agricultural production as much as possible to the current climate changes, which have a significant impact on its development.

Materials and methods

The aim of the paper is to monitor the relationship between the environmental performance of agricultural production and climate change, as well as the homogeneity of the countries of the European Union according to the effect of agricultural production on the occurrence of climate change. In order to achieve the set goal, it is assumed that

1) *there is a positive correlation between the environmental performance of agricultural production and both overall environmental performance and climate change–related environmental performance* and

2) *the countries of the European Union are not homogeneous according to the achieved level of environmental performance in agriculture and climate change*.

The empirical foundation of this research is based on secondary data obtained from the Environmental Performance Index (EPI), published by the Yale Center for Environmental Law and Policy at Yale University in collaboration with the Center for International Earth Science Information Network of Columbia University, as presented in the 2024 annual report. The 2024 EPI evaluates and ranks 180 countries using 58 environmental performance indicators organized into 11 issue categories, which are further aggregated into three overarching policy objectives: Environmental Health, Ecosystem Vitality, and Climate Change. In order to monitor progress towards sustainable intensification of agricultural production, the Environmental Performance Index within the issue category *Agricultural* (which is part of the component - Ecosystem Vitality) monitors the productivity of agricultural production and the excessiveness of pesticides use. The contribution of agriculture to climate change and habitat loss is taken into account through a special component - Climate Change, which consists of the issue category - *Climate Change Mitigation* (Block et al., 2024).

EPI provides a tool to track countries' progress towards meeting UN Sustainable Development Goals and other international policy targets. The, SDGs include several goals directly focused on environmental sustainability, one of which is Climate Action (SDG 13). The research focuses on the 27 member states of the European Union, as defined in 2024, with no exclusions. This selection ensures comparability across countries with harmonized agricultural and environmental policies under the EU framework. The EPI data were used in their original form (without modification), as they provide standardized, internationally comparable metrics for environmental performance. To test the proposed hypotheses, correlation analysis was employed to assess the relationships among the observed variables, while cluster analysis using Ward's method was applied to classify European Union countries according to their levels of environmental performance in agriculture and climate change mitigation. Data processing and statistical analysis were conducted using SPSS software.The use of these EPI metrics allows for the identification and understanding of the state of agricultural production in European Union countries in terms of sustainability as well as climate change mitigation efforts.

Results and Discussions

To evaluate the environmental performance of European Union countries, descriptive statistics for the variables included in the analysis are presented in Table 1.The value of the EPI index for the countries of the European Union ranges from 54 to 75.3, while the maximum possible value of this index is 100. The first twenty countries in the ranking according to environmental performance in the world are European countries during 2024, whose average value is 65.75. Estonia (75.3) ranks first in the world ranking according to environmental performance, followed by Luxembourg, Germany, Finland, Austria and Denmark. Cyprus is the lowest ranked country in the European Union according to the environmental performance value (54.00). According to the category - *Agricultural*, a value of as much as 78.8 was achieved by Germany, which is the fourth country on the score list of the best performances. Germany is a leader in introducing pesticide-free non-organic farming systems, which are easier for producers to adopt than full organic farming and have less associated yield losses (Finger & Niklas, 2024). According to the level of environmental performance in agriculture, Cyprus has the lowest value of 35.70, which places it in the 162nd place in the world ranking of 180 countries. Estonia is the leader among countries at the global level according to the issue category *Climate Change Mitigation* with a value of 82.8, reducing the level of greenhouse gas emissions by 40% over the last decade (Block et al., 2024), while Cyprus achieves very poor results (42.60) in mitigating climate change. In addition to the minimum, maximum, and mean values of the analyzed indicators, Table 1 also reports the standard deviation and the coefficient of variation for each observed category within the sample of EU countries. Closely the same level of variability is present among the EU countries when categories *Agriculture* and *Climate Change Mitigation* are observed. Approximately the same level of variability is present among EU countries when observing issue categories, *Agriculture* and *Climate Change Mitigation*.

Table 1. Descriptive statistics of the observed category

	N	Minimum	Maximum	Mean	Std. Deviation	Variation Coefficient
EPI24	27	54	75.3	65.7513	5.68259	8.64248
Agricultural24	27	35.70	78.80	65.2815	10.21598	15.64912
Climate Change Mitigation24	27	42.60	82.80	57.7444	8.87058	15.36179

Source: Authors' calculation

The initial phase of the analysis focuses on examining the relationship between agricultural production and overall environmental performance, as well as its influence on climate change across EU countries. To identify the degree of interdependence among the observed variables, correlation analysis was employed. Subsequently, cluster analysis was applied to assess the homogeneity of EU countries based on their achieved levels of environmental performance in agriculture and climate change mitigation.

To test the initial assumptions, both correlation and cluster analyses were employed. Correlation analysis was used to examine the relationships between the environmental performance of agricultural production and overall environmental performance, as measured by the Environmental Performance Index (EPI), as well as between the environmental performance of agricultural production and climate change mitigation performance across EU countries. The strength and direction of these relationships were assessed using the Pearson correlation coefficient. Table 2 presents the values of the Pearson correlation coefficient (p) along with the corresponding levels of statistical significance (sig.) for the analyzed relationships. The results reported in Table 2 indicate the existence of a positive correlation between EPI and agricultural performance, with the highest correlation observed between EPI and climate change mitigation performance. The interdependence monitored on the basis of the value of the Pearson coefficient between the issue categories *Agricultural* and *Climate Change Mitigation* is of a moderate level. There is a moderate to strong statistically significant positive correlation between the variables included in the analysis. The obtained results of the existence of interdependence between the analyzed variables confirm the first assumption of the research. Namely, the existence of interdependence between the issue category *Agricultural* and the effect on EPI and the issue category *Agricultural* as well as the issue category *Climate Change Mitigation* in the countries of the European Union was established.

Table 2. Correlation matrix

		EPI2024	Agricultural24	Climate Change Mitigation24
EPI2024	Pearson Correlation	1		
	Sig. (2-tailed)			
	N	27		
Agricultural24	Pearson Correlation	.412*	1	
	Sig. (2-tailed)	.003		
	N	27	27	
ClimateChangeMitigation24	Pearson Correlation	.776**	.601	1
	Sig. (2-tailed)	.000	.002	
	N	27	27	27
*. Correlation is significant at the 0.05 level (2-tailed).				
**. Correlation is significant at the 0.01 level (2-tailed).				

Source: Authors' calculation

As the existence of a positive correlation between agricultural production and climate change has been confirmed, we move on to the second part of the analysis. In order to quantitatively investigate the impact of agricultural production and the occurrence of changes in the climate, an analysis of the aggregation of European Union countries according to the achieved environmental performance within the issue categories *Agriculture* and *Climate Change Mitigation* was performed. The existence of three clusters was identified when classifying the countries of the European Union according to environmental performance within the issue categories *Agriculture* and *Climate Change Mitigation* (Table 3).

Table 3. Distribution of European Union countries by clusters according to the values of issue categories - *Agriculture* and *Climate Change Mitigation* in 2024

Cluster	N	Max	Min	Mean	Country
1	11	74.2 (Agricultural)	64.4 (Agricultural)	69.6 (Agricultural)	Austria, Bulgaria, Croatia, Czech Republic,Hungary,Ireland,Latvia, Lithuania, Poland, Romania, Slovakia
		56 (Climate Change Mitigation)	45.7 (Climate Change Mitigation)	51.34 (Climate Change Mitigation)	
2	10	78.8 (Agricultural)	64.1 (Agricultural)	70.09 (Agricultural)	Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Luxembourg, Nederlands, Sweden
		82.8 (Climate Change Mitigation)	59.7 (Climate Change Mitigation)	66.49 (Climate Change Mitigation)	

Cluster	N	Max	Min	Mean	Country
3	6	56.7 (Agricultural)	35.7 (Agricultural)	49.35 (Agricultural)	Cyprus, Italy, Malta, Portugal, Slovenia, Spain
		63.6 (Climate Change Mitigation)	42.6 (Climate Change Mitigation)	54.9 (Climate Change Mitigation)	
Sum	27				

Source: Authors' calculation

Cluster 2 demonstrates the highest level of performance, followed by Cluster 1, while Cluster 3 exhibits the lowest overall performance. The second cluster includes ten countries of the European Union (Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Luxembourg, Nederlands, Sweden) that strive for sustainable agricultural production and moderately use nitrogen fertilizer and pesticides, which was confirmed by the research, if we bear in mind that the average value within this cluster of ecological agricultural performance is 70.06. The maximum value of *Agriculture* within the cluster is 78.8 and the minimum is 64.1 - they can be associated with sustainable nitrogen management (less than 70 kg per hectare per year) (Zhang et al., 2015) while increasing the yield of agricultural production in the countries of the second cluster. All the countries in this cluster strive to remove subsidies that can create "perverse incentives" for excessive fertilization, which causes serious damage to both the climate and the environment (Zhang, 2017). Along with the efficient use of nitrogen in agriculture, it is also characteristic of the countries of the second cluster that they take care of the emission of gases that create a greenhouse effect and influence the occurrence of climate change. High values of the issue category *Climate Change Mitigation* (maximum 82.8) for countries gathered in this cluster are typical - because they strive to mitigate climate change by using renewable energy sources (minimize carbon emissions) and encourage decarbonization of all sectors of the economy. The average value of the analyzed issue category *Climate Change Mitigation* within the group is at a significant level of 66.49, while the minimum value is 59.7. It can be concluded that the countries comprising the second cluster exhibit a high degree of homogeneity across the analyzed key categories, wherein the attained level of environmental performance in agriculture is closely associated with climate performance. Controlled use of nitrogen does not contribute to the intensive emission of greenhouse gases that are the cause of climate change.

Cluster 1 consists of 11 countries of the European Union (Austria, Bulgaria, Croatia, Czech Republic, Hungary, Ireland, Latvia, Lithuania, Poland, Romania, Slovakia) whose environmental performance in the field of agriculture is at approximately the same level as for the countries of the European Union classified in cluster 2, bearing in mind that the maximum value is 74.2, and the minimum is 69.9. The difference compared to cluster numbe 2 is in the environmental performance in the area of

Climate Change Mitigation, where the average value is low (51.34). This indicates that countries from this group are directed towards carrying out agricultural production in an ecologically acceptable manner with highly efficient application of nitrogen. Owing to the uneven application of nitrogen in agricultural production, which adversely affects climatic conditions, this cluster is characterized by comparatively lower performance in the domain of *Climate Change Mitigation*. More precisely, the group of countries of cluster 1 strives to fight climate change caused in part by agricultural production and strives to mitigate it.

The remaining six countries (Cyprus, Italy, Malta, Portugal, Slovenia, Spain) of the European Union are in the third cluster. This cluster is characterized by low environmental performance in the area of *Agriculture* with a maximum value of 56.7 and a minimum of 35.7, while the performance in the area of *Climate Change Mitigation* is at a slightly higher level than in cluster 1, with an average value of 54.9. Overall, countries within the third cluster adhere to the principles advocating the reduction of greenhouse gas and pollutant emissions that significantly impact the atmosphere; however, their agricultural production is simultaneously characterized by high output levels achieved through the intensive use of nitrogen fertilizers, which poses a substantial threat to the environment.

Table 4. Independent Samples Test

		Levene's Test for Equality of Variances		**t-test for Equality of Means**		
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**
Agricultural24	Equal variances assumed	1.020	.330	-5904	14	**.000**
	Equal variances not assumed			-5.371	7.940	**.001**
ClimateChange24	Equal variances assumed	.105	.751	-3.177	14	**.007**
	Equal variances not assumed			-3.197	10.874	**.009**

Source: Authors' calculation

T-test for two independent samples (Independent Sample Test) was used to check the statistical significance of differences in the average values of variables (values of issue categories – *Agriculture* and *Climate Change Mitigation*) between clusters. Based on the results presented in Table 4, the values of the significance levels for *Agriculture* and *Climate Change Mitigation* indicate homogeneity of variances within the groups, as well as statistically significant differences in mean values among the clusters, given that the significance level is below 0.05. These findings provide empirical support for the confirmation of the second research assumption. Specifically, the results demonstrate that European Union countries are not homogeneous with respect to their achieved levels of environmental performance in agriculture and climate change mitigation. This was shown by classifying the countries of the European Union into three clusters that are characterized by different levels of achieved environmental performance in the observed categories during the analyzed year.

Conclusions

The challenge of agriculture in the 21st century requires an integrated approach that combines ecological, social, and economic dimensions of development to meet present needs without compromising the well-being of future generations. Agricultural activities significantly affect the environment, the management of natural resources, and climate stability. The interaction between agriculture and climate change is characterized by a complex causal relationship: while agriculture contributes to global warming through greenhouse gas emissions, it also holds potential for climate change mitigation through sustainable practices, emission reduction, and carbon sequestration.

The main empirical findings of this paper confirm a statistically significant positive correlation between agricultural performance, overall environmental performance, and climate change mitigation indicators among EU countries. Cluster analysis revealed three distinct groups of EU member states with different levels of sustainability. Countries such as Cyprus, Italy, Malta, Portugal, Slovenia, and Spain demonstrate lower environmental efficiency and require stronger efforts to adopt sustainable agricultural practices that can reduce greenhouse gas emissions. Policy implications suggest that the findings can support the ongoing reform of the Common Agricultural Policy of the European Union. Policymakers should strengthen agri-environmental measures, promote carbon-efficient farming systems, and encourage innovation in sustainable agricultural technologies. Special attention should be given to supporting lagging regions through targeted incentives, capacity building, and the integration of environmental indicators into performance-based funding mechanisms. Limitations of the study arise primarily from the use of secondary data and aggregated EPI indicators, which may not fully capture specific regional variations or sectoral nuances. Future research should focus on detailed case studies of individual EU member states, the inclusion of time-series data to analyze trends, and the integration of economic performance indicators (e.g., agricultural productivity, investment efficiency, and rural income). This would allow a more comprehensive understanding of the interplay between agricultural sustainability, environmental performance, and economic development in the European context.

Conflict of interests

The authors declare no conflict of interest.

References

1. Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *Proceedings of the National Academy of Sciences, 115*(25), 6506–6511. https://doi.org/10.1073/pnas.1711842115
2. Block, S., Emerson, J. W., Esty, D. C., De Sherbinin, A., Wendling, Z. A., et al. (2024). *2024 Environmental performance index*. Yale Center for Environmental Law & Policy. https://epi.yale.edu/
3. Cui, X., Bo, Y., Adalibieke, W., Winiwarter, W., Zhang, X., Davidson, E. A., ... & Zhou, F. (2024). The global potential for mitigating nitrous oxide emissions from croplands. *One Earth, 7*(3), 401–420. https://doi.org/10.1016/j.oneear.2024.01.005
4. Dabkiene, V., Balezentis, T., & Streimikiene, D. (2021). Development of agri-environmental footprint indicator using the FADN data: Tracking development of sustainable agricultural development in Eastern Europe. *Sustainable Production and Consumption, 27*, 2121–2133. https://doi.org/10.1016/j.spc.2021.05.017
5. European Commission (EC). (2019). Agriculture and climate change. https://ec.europa.eu/info/food-farming-fisheries/sustainability-and-natural-resources/agriculture-and-environment/agriculture-and-climate-change_en?cookies=disabled
6. European Commission (EC). (2021). Climate change - driving forces. *Eurostat Statistics Explained*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Climate_change_-_driving_forces#Agricultural_emissions
7. European Commission (EC). (2023, November 13). Study on options for mitigating climate change in agriculture by putting a price on emissions and rewarding carbon farming. https://climate.ec.europa.eu/news-your-voice/news/looking-how-mitigate-emissions-agriculture-2023-11-13_en
8. European Environmental Agency (EEA). (2024). Greenhouse gas emissions from agriculture in Europe. https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-agriculture
9. Finger, R., & Niklas, M. (2024). The emergence of pesticide-free crop production systems in Europe. *Nature Plants, 10*(3), 360–366. https://doi.org/10.1038/s41477-024-01650-x
10. Food and Agriculture Organization (FAO). (2011). *The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk*. Food and Agriculture Organization of the United Nations.
11. Ilić, I. (2022). *The effects of integration of ecological measures in the Common agricultural policy of the European Union* (Doctoral dissertation). University of Nis, Serbia. https://phaidrani.ni.ac.rs/view/o:1902

12. Intergovernmental Panel on Climate Change (IPCC). (2023). *Summary for policymakers*. In *Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1–34). Geneva, Switzerland. https://doi.org/10.59327/IPCC/AR69789291691647.001
13. International Energy Agency (IEA). (2023). *World Energy Outlook 2023*. https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2aedf61467e070/WorldEnergyOutlook2023.pdf
14. Krstič, M. (2024). Agriculture and greenhouse gas emission – results of econometric analysis. *Ekonomika Poljoprivrede, 71*(2), 427–441. https://doi.org/10.59267/ekoPolj2402427K
15. Larsen, A. E., Gaines, S. D., & Deschênes, O. (2017). Agricultural pesticide use and adverse birth outcomes in the San Joaquin Valley of California. *Nature Communications, 8*(1), 302. https://doi.org/10.1038/s41467-017-00349-2
16. Lenton, T. M., McKay, D. I. A., Loriani, S., Abrams, J. F., Lade, S. J., Donges, J. F., ... & Rockström, J. (2023). *The global tipping points report 2023*. University of Exeter. https://global-tipping-points.org
17. Martin, M., Elnour, M., & Siñol, A. C. (2023). Environmental life cycle assessment of a large-scale commercial vertical farm. *Sustainable Production and Consumption, 40*, 182–193. https://doi.org/10.1016/j.spc.2023.06.020
18. Milinčić, M., Tucović, M., & Mandić, B. (2013). Some aspects of agricultural influence on the environment. *Collection of Papers - Faculty of Geography at the University of Belgrade., 61*, 31–58. https://scindeks-clanci.ceon.rs/data/pdf/1450-7552/2013/1450-75521361031M.pdf
19. Naam, R. (2013). *The infinite resource: The power of ideas on a finite planet*. UPNE.
20. Ncube, A., Fiorentino, G., Panfilo, C., De Falco, M., & Ulgiati, S. (2024). Circular economy paths in the olive oil industry: A life cycle assessment look into environmental performance and benefits. *The International Journal of Life Cycle Assessment, 29*(8), 1541–1561. https://doi.org/10.1007/s11367-022-02031-2
21. Organisation for Economic Co-operation and Development (OECD). (2016). *Agriculture and climate change: Towards sustainable, productive and climate-friendly agricultural systems*. https://www.oecd.org/agriculture/ministerial/background/notes/4_background_note.pdf
22. Ozdemir, I., Yngson, D. S. M. P., Israel, D., Otundo, J., Beasnael, N., Ceesay, A., & Zaman, A. (2023). COP28. https://www.connaissancedesenergies.org/sites/connaissancedesenergies.org/files/pdf-actualites/cop-presidencies-comparative-analysis-tracked7073-230927011708.pdf
23. Paloviita, A., & Järvelä, M. (2015). Climate change adaptation and food supply chain management: An overview. In *Climate change adaptation and food supply chain management*. 19–32. Routledge. http://urn.fi/URN:NBN:fi:jyu-201709193760

24. Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science, 360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216
25. Popp, J., Pető, K., & Nagy, J. (2013). Pesticide productivity and food security: A review. *Agronomy for Sustainable Development, 33*(1), 243–255. https://doi.org/10.1007/s13593-012-0105-x
26. Pretty, J. (2018). Intensification for redesigned and sustainable agricultural systems. *Science, 362*(6417), eaav0294. https://doi.org/10.1126/science.aav0294
27. Radivojević, V., Krstić, B., Krstić, M., & Petković, M. (2019). Benchmarking agricultural and other environmental performances of Central and East European countries. *Ekonomika Poljoprivrede*, *66*(2), 471–484. https://doi.org/10.5937/ekoPolj1902471
28. Ritchie, H., & Roser, M. (2024). Half of the world's habitable land is used for agriculture. *Our World in Data*. https://ourworldindata.org/global-land-for-agriculture?ref=insights.onegiantleap.com
29. Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., ... & Willett, W. (2018). Options for keeping the food system within environmental limits. *Nature, 562*, 519–525. https://doi.org/10.1038/s41586-018-0594-0
30. van Der Werf, H. M., Knudsen, M. T., & Cederberg, C. (2020). Towards better representation of organic agriculture in life cycle assessment. *Nature Sustainability, 3*(6), 419–425. https://doi.org/10.1038/s41893-020-0489-6
31. Wang, Q. J., Wang, H. J., & Chang, C. P. (2022). Environmental performance, green finance and green innovation: What's the long-run relationships among variables?. *Energy Economics, 110*, https://doi.org/10.1016/j.eneco.2022.106004
32. Zhang, X. (2017). A plan for efficient use of nitrogen fertilizers. *Nature, 543*, 322–323. https://doi.org/10.1038/543322a
33. Zhang, X., Davidson, E. A., Mauzerall, D. L., Searchinger, T. D., Dumas, P., & Shen, Y. (2015). Managing nitrogen for sustainable development. *Nature, 528*, 51–59. https://doi.org/10.1038/nature15743
34. Żukowska, G., Myszura, M., Baran, S., Wesołowska, S., Pawłowska, M., & Dobrowolski, Ł. (2016). Agriculture vs. alleviating the climate change. *Problemy Ekorozwoju, 11*(2), 67–74. https://ph.pollub.pl/index.php/preko/article/view/4944