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Farm Carbon Footprint Measurement Frameworks Based on the Digitization and Environmental Sustainability Paradigm

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Abstract. *The use of digital technology in agriculture, such as sensors, satellites, and artificial intelligence, for developing sustainable agriculture and controlling the impacts of climate change, has been enhanced under the European Green Deal. Given the environmental exigencies, the agricultural sector must adapt to new technologies that ensure the sustainable development of the whole agri-food sector. This paper emphasizes the importance of measuring carbon footprints in agriculture as a tool for further improving the sustainability of the sector. Specifically, the research addresses the importance of sustainable technologies and practices, including agriculture, circular economy, and conservation agriculture, which play an important role in reducing carbon emissions from the agricultural sector. Thus, in the framework of the European Green Deal and digitalization, a bibliographic analysis was carried out using the Web of Science database to review the scientific interest on carbon footprint generated by farms. The aim of the paper is to tackle the significance given by the scientific community on the carbon footprint of farms in order to enhance the development of a comprehensive set of measures that can incorporate the sector's social and environmental responsibility, and ensure further the right path towards a sustainable future without affecting the profitability of the small farmers.*

Keywords: carbon footprint, agriculture, sustainable development, European Green Deal, environmental sustainability, digitization

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Introduction

The European Green Deal is the EU's constant effort to tackle the complex problems associated with climate change, as the decline in biodiversity and to adopt the right approach to further appropriate the use of natural resources. The action focuses on the transition to a circular economy as well as the contribution of the agricultural sector to the environment. In this context, attempts to control the impact of carbon and greenhouse gas emissions apply to all areas and particularly to agriculture. The utilization of digital technology in the agricultural sector is a valuable instrument for attaining enhanced resource management and mitigating environmental impacts (Pandey & Agrawal, 2014). The new EU agenda entails the use of cutting-edge technologies, including sensors, satellites, and artificial intelligence, to gather and analyze up-to-date data (European Commission, 2019a,b; Faichuk et al., 2022). Through the process of quantifying and evaluating the carbon footprint, a more comprehensive understanding of the environmental ramifications of agricultural practices can be calibrated in order to ensure sustainable development across EU member states (Ozlu et al., 2022; Istudor et al., 2021). This enables the identification of specific domains where modifications can be introduced to mitigate the release of greenhouse gases (Gil et al., 2019). Given the prevailing conditions, it has become vital to priorities the identification and reduction of the carbon footprint (Holka et al., 2022); is critical to reduce the negative effects of greenhouse gas emissions and ensure the implementation of the Paris Agreement targets (Aslan et al., 2020) for maintaining a food-safety and security level that can meet a growing population need. However, there is no systematic study and evidence for the carbon footprint of the agricultural practices even though it is a strongly debated issue in the field literature, as a source of greenhouse gas emission. Having in mind that the carbon footprint concept was incorporated after into the European strategies and policies, more specifically by such initiatives as the European Green Deal and the digitalization process, included in the strategic document of Agenda 2030 (United Nations, 2015), there has been developed a significant potential for the research in the field of carbon footprints and the assessment of carbon emissions of the agricultural operation (Rebolledo-Leiva et al., 2017).

Understanding these facets has significant importance given the European Green Deal and the ongoing process of digitization within the contemporary milieu (Gosnell et al., 2019). The purpose of this study is to better understand the relationship between the carbon footprint and agriculture sector in the context of digitalization and the use of tools from the European Green Deal. Furthermore, the study aims to provide a deep knowledge of current practices and challenges in the quantification of agricultural carbon emissions and how the digitization process can overcome these barriers effectively. With better estimation and quantification of carbon emissions originating from agricultural practices, policymakers and farmers can judge the environmental repercussions of their own activities and can finally make definite strategies toward reducing their carbon footprints (Chiaramonti et al., 2021). The current research also supports the possibility that sustainable agriculture could reduce the effects of climate change and also help in the preservation of natural resources (Wang et al., 2019).

Materials and methods

Scientometrics is a discipline that focuses mainly on providing a scientific basis for the improvement of scientist research. The main objective of the field of scientometrics is to simplify the complexity of the academic world through quantitative approaches by examining many characteristics, such as the scientific output or the impact of research, and converting them into statistical information.

Scientometrics is an empirical approach to analyzing and unveiling some of the intricate patterns and trends underlying the entire scientific study that is analyzed (Gerry McKiernan AB, 2005). This discipline is based on rational approaches, in particular the organization and analysis of data on these indicators, which provides deep knowledge of the applied methodologies and their application at global level. In the present study the methodology was employed for the investigation of the carbon footprint of farms within the framework of the European Green Deal and the process of digitization. The process involved analyzing multiple sources of information. In general terms, this process can include a database of bibliographic databases such as Scopus, Google Scholar and Web of Science, which assembles a large number of scientific articles. The Web of Science database was used in this article to provide a broader range of indexed articles over the period extending to the adoption of the European Green Deal. Bibliometrics is a highly intriguing and specialized area within the domain of scientometrics (Hood & Wilson, 2001). This subdiscipline involves quantitative analysis of scientific publications in a statistical and analytical context, with the aim of providing comparisons and evaluations of knowledge creation based on existing knowledge. This provides a robust methodology for analysis and comparison of scientific activities in different areas of research, countries, or academic institutions. The aspect of library measurement encompasses its characteristic criticalness, in which complex measurement is used to measure academic activities. These metrics facilitate the identification of emerging patterns and shifts in the significance of research areas by analyzing data derived from the processing of scientific publications (Broadus, 1987). This research is also aimed at identifying new research topics and trends in research development, whether they are increasing or declining.

The fundamental distinction between bibliometrics and scientometrics can be comprehended in terms of their precision and distinct objectives. In fact, biblimetrics is a systematic method of quantitative assessment of scientific research; it is a method of accessing and analyzing scientific outputs by certain indicators, such as the number of publications, the impact of citations and the impact of factors on journals. Specifically, it deals with the publishing process and the general characteristics of scientific information, which means that it has a fairly integrated view of the field of research. In contrast to the aforementioned, scientometrics has a wider range of activities and methods that focus on the overall analytical assessment of scientific research, emphasizing on the qualitative characteristics and general impact of research. The main purpose of this discipline is to analyze and evaluate research efforts and resource funding in specific research sectors. It also helps to understand the dynamism of collaboration networks and the other social impacts of research efforts. These methods have led to progress in knowledge and benefits for society on a wide range of fields, from the social sciences and humanities to the precise and technical sciences. Consequently, although their nature is very independent, library and scientific analysis are today of great importance and relevance in the world of learning, consolidating an important basis in the field of research and development. Hence, an overall analysis of the carbon footprint of farms under the European Green Deal and digitization can be done from a number of research perspectives, one of them being the bibliometric analysis. Therefore, taking into account the quantitative analysis methods, a bibliometric analysis was employed by using the software package VOSviewer in the study of the field literature.

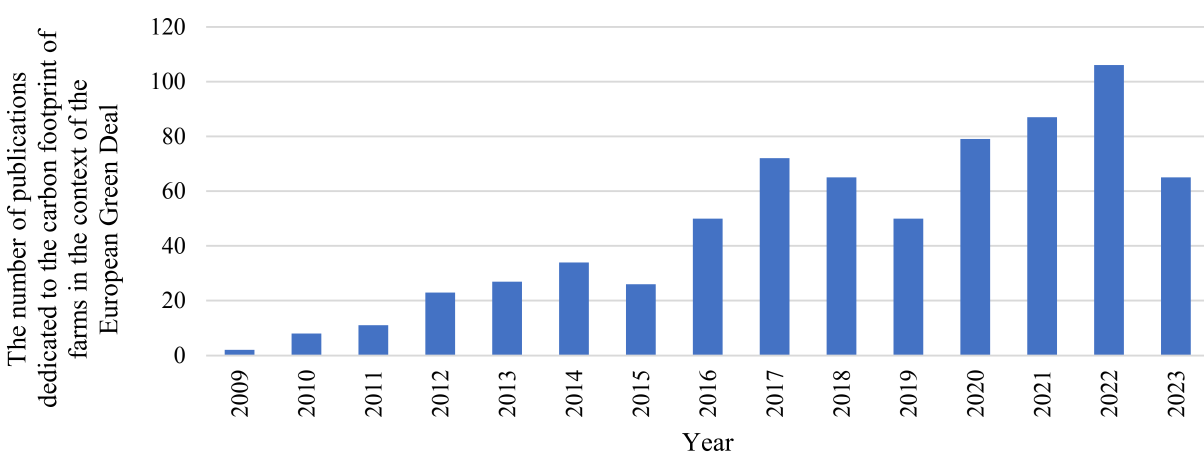
The software was developed and executed by Nees Jan van Eck and Ludo Waltman, two researchers affiliated with the Centre for Science and Technology Studies at Leiden University (van Eck & Waltman, 2019). VOSviewer is a valuable quantitative research tool that demonstrates significant promise for visually representing the interrelationships of keywords connected with the publications under investigation (van Eck & Waltman, 2017). The software allows users to visually analyze the frequency and relationship of keywords in the scientific literature. The study examined the carbon footprint of agricultural farms in the context of the European Green Deal and digitalization. The literature query has been carried out in the Web of Science database on the English search query "carbon footprint," "farm," and "agriculture." In total, 705 works have been detected according to the specified conditions since 2009. Identification was carried out in accordance with the given specifications, applying terms associated with the Web Science query.

Results and discussions

The agriculture sector has been recognised as a substantial source of greenhouse gas emissions, thereby making a notable contribution to the phenomenon of global climate change. In recent years, there has been a proliferation of scientific viewpoints about the assessment of carbon footprint within this particular industry (Yang et al., 2014). Nonetheless, a dearth of clarity and agreement persists on the most precise and all-encompassing approach to quantifying and evaluating the carbon footprint within the realm of agriculture (Martin-Gorriz et al., 2021).

This study seeks to address the lack of information in this area by conducting a comprehensive review of the current scientific literature. The objective is to enhance our comprehension of the different strategies, procedures, and instruments employed in assessing carbon footprint within the agricultural sector (Hu et al., 2019). Figure 1 displays a graph illustrating the progress of academic research over the years, as indicated by the index. A significant increase in scientific interest can be observed from 2009 (2 published papers) to 2023 (65 published papers), the first upsurge of scientific interest begins after 2015, the year in which the Agenda 2030 document was adopted, introducing the term sustainability in relation to the productive sectors of a state's economy. Moreover, a 30% increase in the 2023 compared to the 2019, can also be observed in the scientific community's interest regarding the relationship between the "carbon footprint" and "farm", the year 2019 marking the adoption of the European Green Deal, which proposes certain requirements for maintaining the relationship between agriculture and the environment.

Figure 1. The evolution of publications dedicated to the issue of the carbon footprint of farms in the context of the European Green Deal



Source: Authors' own processing based on data extracted from the Web of Science.

Figure 2 shows a group of key study words that help explain the deeper nature of these relationships. The construction of this figure involved the utilisation of co-occurrence analysis, wherein terms derived from the title, abstract, or keywords were considered, and counting was employed as the method of quantification. Inclusion of keywords in Figure 3 was contingent upon their occurrence frequency of at least five instances within a total word count of 3021.

Table 1 presents the ranking of the thirty frequently used terms in relation to the key words of the study, which appear in the published works of the scientific community between 2009-2023, the presence of keywords such as "life-cycle assessment", "agriculture", "management" or "sustainability" suggests the need to implement management practices that take into account the natural relationships between ecosystems to ensure the long-term sustainable development of the agricultural sector. Figure 2 depicts graphically the relationship between the keywords presented in the table, while in Figure 3 the correlation over time of the keywords is highlighted, taking into account the elements brought by the European Commission in 2019 through the European Green Deal, but also the impact produced by the 2030 Agenda in 2015. Consequently, this paper undertakes the realization of the field of research by a coherently viewed trend and pattern, hence delivering a comprehensive survey over time horizons. The analysis of the data and the summaries, both graphical and tabulated, facilitate the deciphering of the trajectory and focus being undertaken for this research paper.

Table 1. Top thirty recurring terms identified in the metadata of the analyzed publications on the subject of the carbon footprint of farms in the context of the European Green Deal

Ranking	Term or term structure	Number of occurrences	Intensity of the correlations
1	carbon footprint	452	3308
2	greenhouse-gas emissions	243	2041
3	life-cycle assessment	216	1726
4	life cycle assessment	155	1275
5	agriculture	104	828
6	management	96	785
7	sustainability	94	711
8	systems	89	695
9	environmental impacts	81	682
10	emissions	72	526
11	lca	72	569
12	mitigation	69	583
13	milk-production	66	572
14	energy	64	463
15	production systems	52	446
16	greenhouse gas emissions	48	367
17	soil	48	367
18	impacts	47	365
19	climate change	46	334
20	methane	46	387
21	impact	45	339
22	climate-change	43	343
23	efficiency	43	338
24	performance	43	312
25	greenhouse gas	41	344
26	livestock	41	318
27	nitrous-oxide emissions	41	342
28	environmental impact	39	323
29	variability	38	329
30	sequestration	38	333

Source: Authors' own processing based on data extracted from Web of Science.

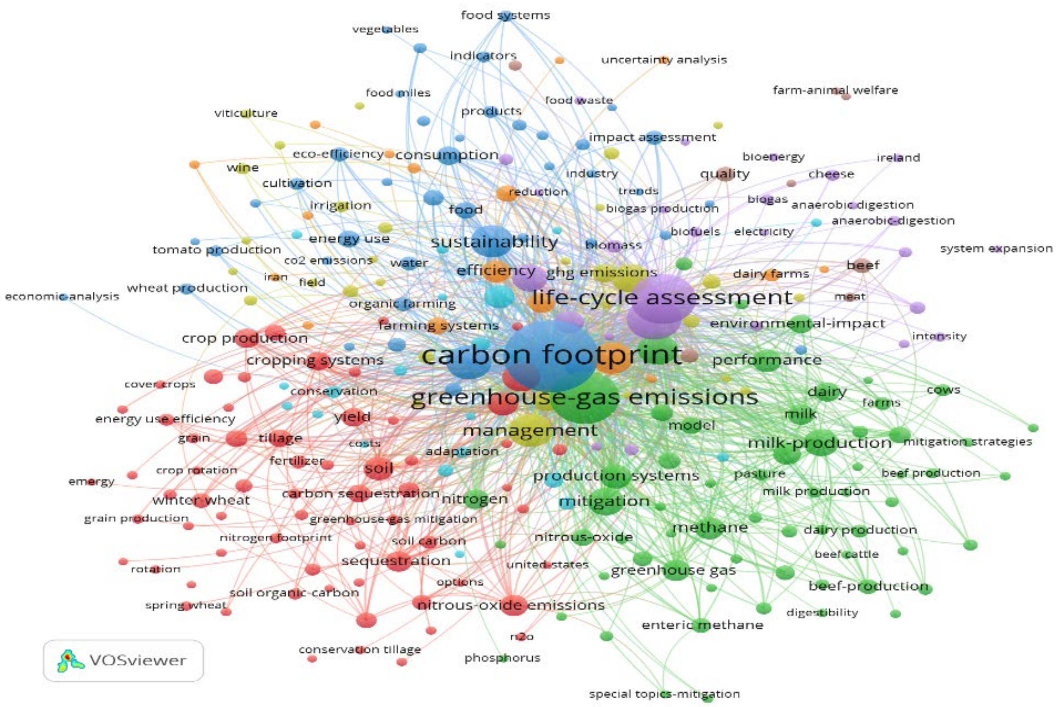


Figure 2. Analysis of correlations between the words associated with publications dedicated to the carbon footprint of farms in the context of the European Green Deal

Source: Authors' own processing in VOSviewer 1.16.19.

Farms play a crucial role in both the agricultural sector and the food industry. The individuals in question bear the responsibility for the cultivation and extraction of sustenance and primary resources, including but not limited to dairy, meat, grains, and the like. At the same time, their operations exert a significant impact on the ecosystem. Nowadays, agribusinesses are forced to become more and more efficient in their working in the context of sustainability. The measurement of carbon emissions caused by the production process in agriculture and animal husbandry represents an assessment of their ecological effectiveness, or in other words, the carbon footprint. Within the framework of the European Green Deal, agricultural establishments are mandated to curtail their emissions of greenhouse gases and implement measures aimed at mitigating their ecological footprint. In this context, the green cluster in Figure 3 contains terms related to ammonia, balance, beef cattle, beef-production, carbon dioxide, cows, dairy production system, enteric methane emissions, greenhouse gas emissions, livestock, manure, farms, performance, mitigation strategies. This cluster is designed to give a proper view of the problems associated with the farm's carbon footprint and how to design efficient mitigation strategies for minimizing environmental impact. The carbon footprint of farms is mainly dictated by beef production and dairy production systems. Such operations serve as the main influencing factor in the generation and emission of greenhouse gases, particularly carbon dioxide (CO2) and methane (CH4). Without doubt, methane is of a more critical nature regarding global warming in comparison to carbon dioxide; however, it has to be mentioned that emissions of CO2 are also considerable because the amount of energy that needs to be consumed for the production of feed and for the process of husbandry in these farms is far from negligible. In most systems, there is a direct positive relationship between the quantity of milk produced and the CO2 emitted. The reason for this is that in the case where a high number of cows are being reared, more feed needs to be produced to support them, and consequently, more milk would be obtained. Therefore, in these systems, a sensible meat-to-milk ratio has to be established to minimize the magnitude of poor environmental impacts.

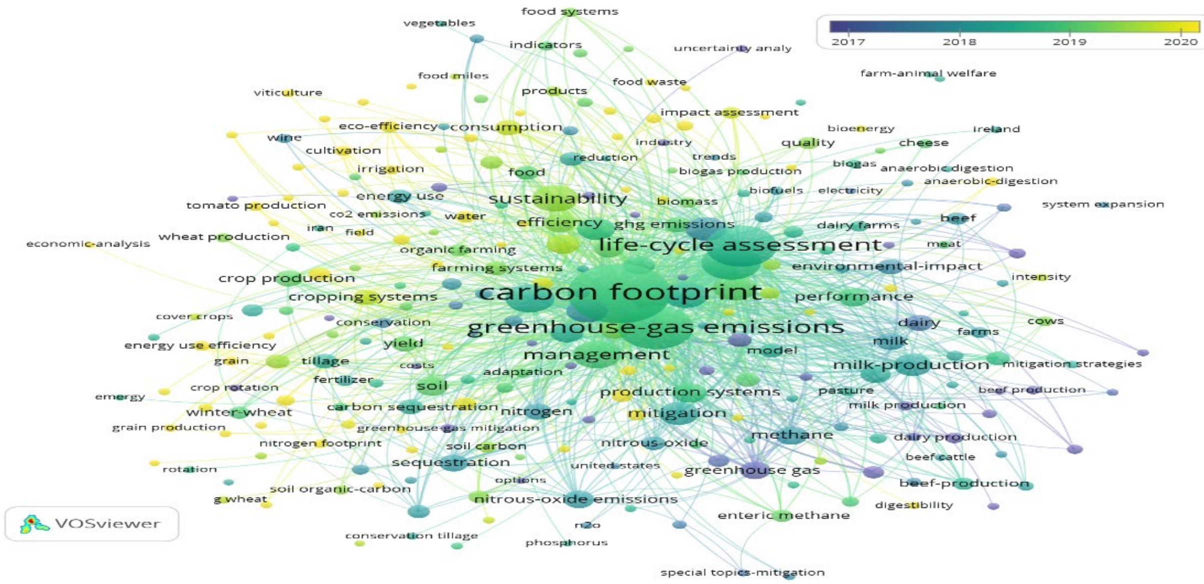


Figure 3. Analysis of the evolution of the correlations between the terms associated with the publications aimed at the carbon footprint of farms in the context of the European Green Deal

Source: Authors' own processing in VOSviewer 1.16.19.

Another important factor in this group relates to methane emissions, particularly enteric methane emissions, which are those produced during the digestion process of animals. Cattle are among the large emitters of methane, and their digestive process, ruminating, and stomach fermentation are mostly to blame. Furthermore, the cluster highlighted the blue colour in Figure 3 comprises terms such as agroecology, aquaculture, carbon footprint, circular economy, climate change, CO_2 emissions, eco-efficiency, energy consumption, food miles, life cycle analysis, supply chain, sustainable agriculture, water, vertical farming, and urban agriculture. This cluster specifically focuses on the topic of the carbon footprint of farms, discussing it in conjunction with the concepts of sustainable agriculture and the European Green Deal. These issues are interrelated and involve the importance of protecting the environment, biodiversity, and natural resources in the context of agricultural production. As already stated, the topics and technologies that are covered by agronomy are vast. All the environmental practices are interrelated in their goals of increasing the efficiency and sustainability of farming, such as the circular economy concept that can be effectively applied in the agricultural sector through the practise of recycling organic waste for utilisation as fertilisers or energy sources.

This red cluster in Figure 3 corresponds to a variety of agricultural practices that include agricultural soils, carbon sequestration, conservation agriculture, mitigation of climate changes, crop rotation, diversity and dynamics, farm size, fertilizer application, land-use change, nitrogen footprint, organic carbon, water-use efficiency, water yields, and total yields. Therefore, this feature is important for understanding the carbon impact of the farms, with particular scrutiny within the perspective of the European Green Deal. It contains the notion that agricultural soils are a strong factor in driving the absorption and retention of carbon from the atmosphere and thereby, they recognize having a huge influence on mitigating greenhouse gases in fighting against climate change. In the academic field of agricultural sciences, the high capacity of soils to store huge amounts of carbon has already been acknowledged and not a new point of view. This process is made possible by the fact that annual plants are able to capture carbon dioxide through the process of photosynthesis and later, transform it into organic carbon molecules, which in turn are kept in the soil. Additional pertinent terms within this cluster are "climate change mitigation", "fertiliser application", "land-use change", and "water-use efficiency". The terms are linked, interrelated, and give an excellent illustration that sustainable agricultural practice adoption will have a significant impact on climate change; as an example of a good environmental practice that can be adopted includes of eliminating the use of chemical fertilizers and usage of water. It also includes preserving the farmland as it is in its natural state and ensuring it remains so, so as to avoid it being turned into degraded land.

Nowadays farm carbon footprint measurement is an important issue for the sustainable development and progress of the society. In this regard, farm-related carbon emission measurements and its carbon foot printing estimation are being important criteria for the global sustainability goals, but the lack of proper standard procedures and measures make the process of estimation difficult. There remains a need for one standard and one set of criteria within which carbon emissions can be measured and reported for use in agricultural application so that uniform and comparable data can be gathered for better efficiency in analysis and decision-making (Apetrei et. al., 2019). Digital technology and practice of precision farming can instantly generate data on the agricultural practices and emissions, while the data generated from such technologies can be used for its carbon footprints. However, this is laced with several problems: the data has to be reliable and accurate, data management and data ownership/privacy, and on the other hand, the ability of small-scale farms that can be resource-poor to access and afford such technologies, in the first place. Thus, the governments and other international organizations need to further stimulate such transformation by providing economic incentives and economic support to make the agricultural sector capable of this transformation process with financial and technical support. Ensuring the effectiveness and practicality of carbon footprint assessment systems and policies is guaranteed by the participation of stakeholders.

Conclusion

In the contemporary context of increasing climate change, the agricultural sector appears to be one of the leading sectors creating huge impacts on the surrounding environment with greenhouse gas emissions. With this concern, farms, especially producing beef and milk through cattle, are demanded to create a leading role for themselves in order to reduce the environmental impact and lower the carbon footprint. This is reflected by the European Green Deal in developing a circular and sustainable economy with the help of reducing carbon emissions and climate change (Naresh Kumar & Chakabarti, 2019). Important for providing the favorable role is the implementation of sustainable agricultural principles and the promotion of practices that enhance microbial activities in soils and increase soil biodiversity in order to foster the advancement of carbon sequestration. In addition, the conservation of the grasslands and other natural ecosystems play the important role in the process of carbon sequestration in the soil and in the process of reducing the emission of the greenhouse gases. The European Green Deal focuses in provision of information and financial support to the farmers for the adoption of such sustainable practices. For the effective mitigation of the carbon footprint, the farmer must be aware of the range of available and repayable technology and practices and will be provided with financial means that can make this possible. More rigorous and effective policy measures and regulatory modes should be applied to ensure that the emission reduction goals are met properly and to promote the sustainability of agriculture.

The emission of carbon and the change in agricultural climate needs the collaboration of all the stakeholders. Furthermore, it is essential that consumers actively participate and take responsibility for their food and in turn encourage the producers and suppliers to integrate such practices. The sustainability in agriculture needs to be improved to ensure that the next generations have a sustainable and a responsible future. In closing, it is essential to note that the research has some limitations such as the sample size of the research related solely to Europe, bearing in mind that its results are thus inapplicable on a global basis; equally, in the undertook research the application of digital technologies lay in the measurement of farm carbon footprints, while the most important key variables involved land use and management practices. The use of a larger, more heterogeneously varied sample will definitely catch the phenomenon of digitization in order to measure the carbon footprints of farms in greater depth.

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References

Apetrei, A., Sánchez-García, J. L., & Sapena, J. (2019). The controversial link between entrepreneurial activity and inequality. *International Entrepreneurship and Management Journal*, *15*(2), 485–502. https://doi.org/10.1007/s11365-019-00560-1

Aslan, A., Altinoz, B., & Özsolak, B. (2020). The nexus between economic growth, tourism development, energy consumption, and CO_2 emissions in Mediterranean countries. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-020-10667-6.

Broadus, R. N. (1987). Toward a definition of "bibliometrics". *Scientometrics*, *12*(5), Article 5. https://doi.org/10.1007/BF02016680.

Chiaramonti, D., Talluri, G., Scarlat, N., & Prussi, M. (2021). The challenge of forecasting the role of biofuel in EU transport decarbonisation at 2050: A meta-analysis review of published scenarios. *Renewable and Sustainable Energy Reviews*, *139*, 110715. https://doi.org/10.1016/j.rser.2021.110715.

de Blas, I., Mediavilla, M., Capellán-Pérez, I., & Duce, C. (2020). The limits of transport decarbonization under the current growth paradigm. *Energy Strategy Reviews*, *32*, 100543. https://doi.org/10.1016/j.esr.2020.100543.

European Commission. (2019a). *The European Green Deal*.

European Commission. (2019b). *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions the European Green Deal*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019DC0640.

Faichuk, O., Voliak, L., Hutsol, T., Glowacki, S., Pantsyr, Y., Slobodian, S., Szeląg-Sikora, A., & Gródek-Szostak, Z. (2022). European Green Deal: Threats Assessment for Agri-Food Exporting Countries to the EU. *Sustainability*, *14*(7), Article 7. https://doi.org/10.3390/su14073712.

Gerry McKiernan AB, M. (2005). Bibliometrics, Cybermetrics, Informetrics, and Scientometrics Sites and Sources. *Science & Technology Libraries*, *26*(2), Article 2. https://doi.org/10.1300/J122v26n02_06.

Gil, J. D. B., Daioglou, V., van Ittersum, M., Reidsma, P., Doelman, J. C., van Middelaar, C. E., & van Vuuren, D. P. (2019). Reconciling global sustainability targets and local action for food production and climate change mitigation. *Global Environmental Change*, *59*. https://doi.org/10.1016/j.gloenvcha.2019.101983.

Gosnell, H., Gill, N., & Voyer, M. (2019). Transformational adaptation on the farm: Processes of change and persistence in transitions to 'climate-smart' regenerative agriculture. *Global Environmental Change*, *59*, 101965. https://doi.org/10.1016/j.gloenvcha.2019.101965.

Holka, M., Kowalska, J., & Jakubowska, M. (2022). Reducing Carbon Footprint of Agriculture—Can Organic Farming Help to Mitigate Climate Change? *Agriculture*, *12*(9), Article 9. https://doi.org/10.3390/agriculture12091383.

Hood, W. W., & Wilson, C. S. (2001). The Literature of Bibliometrics, Scientometrics, and Informetrics. *Scientometrics*, *52*(2), Article 2. https://doi.org/10.1023/A:1017919924342

Hu, Y., Zheng, J., Kong, X., Sun, J., & Li, Y. (2019). Carbon footprint and economic efficiency of urban agriculture in Beijing—A comparative case study of conventional and home-delivery agriculture. *Journal of Cleaner Production*, *234*, 615–625. https://doi.org/10.1016/j.jclepro.2019.06.122.

Istudor, N., Dinu, V., Nitescu, D.C. (2021), Influence Factors of Green Energy on EU Trade, *Transformations in Business & Economics*, *20*(2), pp. 116-130.

Martin-Gorriz, B., Martínez-Alvarez, V., Maestre-Valero, J. F., & Gallego-Elvira, B. (2021). Influence of the Water Source on the Carbon Footprint of Irrigated Agriculture: A Regional Study in South-Eastern Spain. *Agronomy*, *11*(2), Article 2. https://doi.org/10.3390/agronomy11020351.

Naresh Kumar, S., & Chakabarti, B. (2019). Energy and Carbon Footprint of Food Industry. În S. S. Muthu (Ed.), *Energy Footprints of the Food and Textile Sectors* (pp. 19–44). Springer. https://doi.org/10.1007/978-981-13-2956-2_2.

Ozlu, E., Arriaga, F. J., Bilen, S., Gozukara, G., & Babur, E. (2022). Carbon Footprint Management by Agricultural Practices. *Biology*, *11*(10), Article 10. https://doi.org/10.3390/biology11101453.

Pandey, D., & Agrawal, M. (2014). Carbon Footprint Estimation in the Agriculture Sector. In S. S. Muthu (Ed.), *Assessment of Carbon Footprint in Different Industrial Sectors, Volume 1* (pp. 25–47). Springer. https://doi.org/10.1007/978-981-4560-41-2_2.

Rebolledo-Leiva, R., Angulo-Meza, L., Iriarte, A., & González-Araya, M. C. (2017). Joint carbon footprint assessment and data envelopment analysis for the reduction of greenhouse gas emissions in agriculture production. *Science of The Total Environment*, *593–594*, 36–46. https://doi.org/10.1016/j.scitotenv.2017.03.147.

Salmaso, N., Anneville, O., Straile, D., & Viaroli, P. (2018). European large perialpine lakes under anthropogenic pressures and climate change: Present status, research gaps and future challenges. *Hydrobiologia*, *824*(1), 1–32. https://doi.org/10.1007/s10750-018-3758-x.

United Nations. (2015). *Transforming our World: The 2030 Agenda for Sustainable Development A/RES/70/1*.

van Eck, N. J., & Waltman, L. (2017). Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics*, *111*(2), Article 2. https://doi.org/10.1007/s11192-017-2300-7.

van Eck, N. J., & Waltman, L. (2019). VOSviewer Manual. *Leiden: Univeristeit Leiden*, 1–53.
Wang, Z., Zhang, J., & Zhang, L. (2019). Reducing the carbon footprint per unit of economic benefit is a new method to accomplish low-carbon agriculture. A case study: Adjustment of the planting structure in Zhangbei County, China. *Journal of the Science of Food and Agriculture*, *99*(11), 4889–4897. https://doi.org/10.1002/jsfa.9714.
Yang, X., Gao, W., Zhang, M., Chen, Y., & Sui, P. (2014). Reducing agricultural carbon footprint through diversified crop rotation systems in the North China Plain. *Journal of Cleaner Production*, *76*, 131–139. https://doi.org/10.1016/j.jclepro.2014.03.063.