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Exploring the Interaction between Energy Use in Agriculture and Food Production

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Abstract

This study aimed to explore the academic community's interest in the relationship between energy usage and food production through bibliometric analysis. Using the Web of Science database, 819 research documents published between 1980 and 2023 were analysed. The results of the analysis showed an increase in interest in this topic, with the United States, India, Germany, England, and Italy having the highest number of studies in this field. The research categories most commonly used for such studies were Environmental Sciences (22.431%), Energy Fuels (20.551%), Green Sustainable Science Technology (18.045%), Food Science Technology (12.406%), and Biotechnology Applied Microbiology (10.652%). Although these results suggest that there has been an increased interest in this field, the data also revealed that the participation of countries from the global south is modest. Consequently, this study emphasises the need for further investigation of the development of clean energy technology and legislation that promotes the sustainability of food production.

Keywords: energy consumption, food production, agriculture, renewable energy, sustainable development, climate change, bioenergy.

JEL Classification: Q10, Q16.

1. Introduction

An essential economic sector for mankind, namely the agricultural sector, represents the primordial source of resources: food, labour, and even energy, when the results of agriculture are used as fuel for the energy sector (Clairand et al., 2020). Agriculture can be a significant consumer of energy, which can trigger divergent socio-economic and environmental consequences. There is plenty of energy use in

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the agricultural sector, including activities such as the cultivation of crops, irrigation, product processing and storage, transport, distribution and other logistics-related activities (Naresh Kumar, Chakabarti, 2019). Regarding the energy sources used for carrying out activities in the agricultural sector, they include fossil fuels (referring to diesel, gasoline, and natural gas), electricity, and, in some cases, even environmentally friendly energy sources, referring to the renewable energy sources, such as solar, wind, and biomass (Li, Tao, 2017).

The literature is full of papers dedicated to explaining the use of energy in agriculture and its significant harmful environmental impacts, such as greenhouse gas emissions, pollution (in different forms: air and water), and land degradation. Additionally, the high dependence of implementing large-scale agriculture on the fossil fuel market can cause both sectors to become vulnerable to price volatility and supply disruptions (Chivu et al., 2021). Consequently, promoting energy-efficient practices in agriculture represents an ardent ongoing effort from practitioners and scholars with the aim to find sustainable paths designed to reduce the carbon footprint, and to increase the resilience of these economic sectors to energy-related challenges (Acquier et al., 2019).

2. Problem Statement

Forecast Actuator performed by The Food and Agriculture Organisation of the United Nations (FAO) regarding global population growth until 2050 indicates an increase in energy production by approximately 29-30 % in order to meet consumption needs, and significant growth is also expected in the agri-food sector, with approximately 69-70 % if we refer to food production, to meet demand in the new global reference context (Bundschuh et al., 2014). From these forecasts we can deduce that this demographic growth until the year 2050 will lead to the need to make an extraordinary effort, both in the agri-food sector and in the energy sector, in terms of meeting the demand for food production and energy production (Toró, 2023). A large amount of energy will be required for production in the agri-food system, but if we are aware that traditional energy sources are limited, we can say with confidence that without renewable resources, energy demand will not be able to be met in the long term (Andrei et al., 2021). Therefore, to produce energy in the agri-food system, renewable energy sources will be needed, and in the coming years they will certainly be in the spotlight, and significant investments will be made in this sector, so that we move towards the fulfilment of the Sustainable Development Goal 7 – Clean and affordable energy (Agbedahin, 2019).

In the present moment, several investments are made in the production capacities using the renewable energy resources. But a constant reality is that the increase in demand registered in the agri-food sector together with the demographic growth, will lead to a disproportionate increase compared to the projected increase in energy capacities (Clairand et al., 2020). Therefore, it is extremely important that we also make progress in energy efficiency in agri-food production systems. The goal of energy efficiency in the agri-food sector is to produce the same amount of food or even above the level, but using a smaller amount of energy (Sims, 2014). Thus, energy efficiency can be expressed by the ratio between the production process and the energy input in that process (Li, Tao, 2017). But where can energy consumption in the agri-food sector come from? First, it is important to understand that this energy consumption can come from direct energy consumption or indirect energy consumption (Istudor et al., 2022). Direct energy consumption comes from the direct use of energy, through all the activities carried out on the farm, from the processing of raw materials to the other activities, in the different stages of production. Indirect energy consumption represents the energy consumed, before the production and supply of inputs (Naresh Kumar, Chakabarti, 2019). We must consider the fact that the efficient use of energy resources is essential, and not only for increasing agricultural production, or the competitiveness of the agri-food sector, but also for environmental sustainability considerations (Khan, Hanjra, 2009). Therefore, energy efficiency in the agri-food sector contributes to the improvement of many fundamental aspects, such as increased food production and environmental sustainability (Andrei et al., 2021). As we stated at the beginning of this article, increasing food production will be essential, considering the forecast of global population growth (Baer-Nawrocka, Sadowski, 2019). We should also not forget that improving energy efficiency in the agri-food sector is one of the main methods of reducing the environmental footprint, without having to reduce food production itself (Constantin et al., 2023).

According to the calculations made by the United Nations, by 2050 the global population will grow by about two billion, and by 2100 it could increase by up to three billion (Eurostat, 2021). Another rather worrying aspect is the fact that increased energy consumption usually decreases the sustainability of the environment (Popescu et al., 2022); therefore, we must have a conscious behaviour so that we do not further degrade the environment. In addition to this aspect, we know very well that in order to meet human nutritional requirements, we must first overcome the existing limitations in the ability to produce enough energy for food production (Bajan, Mrówczyńska-Kamińska, 2020; Bolandnazar et al., 2014).

Consequently, it is now imperative to comprehend the rationale behind employing energy consumption as an indicator of environmental performance (Li et al., 2022).

3. Research Questions / Aims of the Research

The aim of this investigation is to establish a potential correlation between the amount of energy utilised in agricultural production and the resulting level of food activity generated through processing activities. The existence of a correlation between energy production and the amount of food activity generated as a direct consequence of processing will also be ascertained by evaluating the intensity of the said correlation.

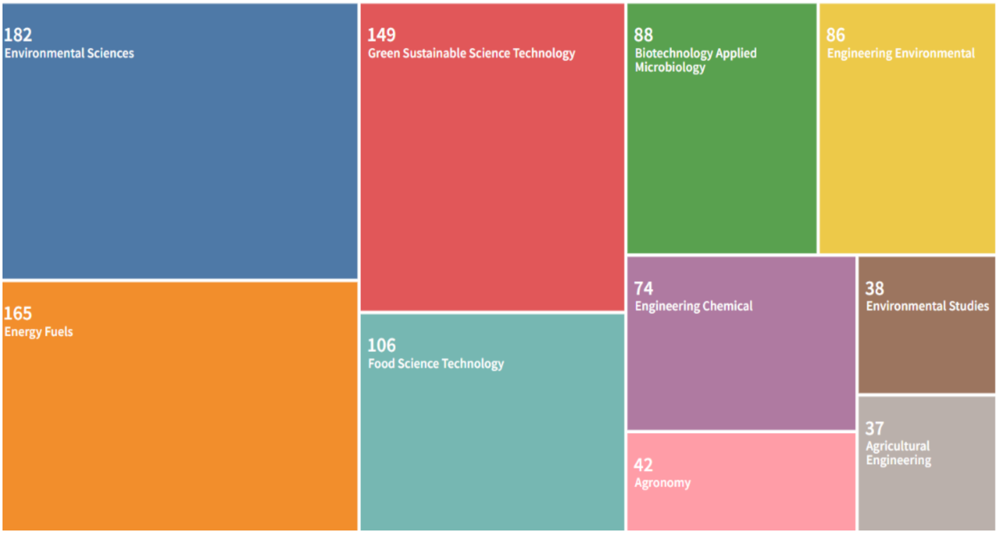
4. Research Methods

The research utilised a scientific approach called bibliometric analysis, which is a type of scientometric methodology. In recent years, the employment of scientometric and bibliometric methodologies has gained significance in the assessment of scientific publications' productivity, expansion, and interrelationships. This is due to the growing need to monitor the links between keywords used in the study of a subject, which is crucial in accurately evaluating the significance of a theme studied by researchers in a particular field (McKiernan, 2005; Hood, Wilson, 2001). Given the aim of the present investigation, it has been ascertained that the utilisation of a quantitative approach is the most suitable tactic for exploring the scientific inquiry concerning the interconnection between food production and energy consumption in agriculture. In the framework of this research, VOSviewer version 1.16.16 was utilised as a means of generating, examining, and visualising maps that incorporate network metadata. To create bibliometric networks through graphical design and generation, it is essential to have a reliable collection of raw data or metadata. The utilisation of VOSviewer assessment is a necessary condition for carrying out bibliometric analysis. The prioritisation of interconnections among metadata within the analysed database is a key feature of VOSviewer (Sood et al., 2021; van Eck, Waltman, 2017, 2019). In April 2023, a search was performed on the Web of Science database, since the current quantitative research assessment is limited to scientific publications that are presently available and indexed in the specific database. The assessment relies on the unprocessed metadata that has been collected and analysed. This study focuses on the subject of energy usage in relation to the interconnections between food production and agriculture. The search query included the terms "energy usage" and "food production". Based on the findings of the inquiry, a cumulative sum of 819 scholarly articles addressed the subject of agricultural trade vis-à-vis the European Union's sustainable development policies. Web of Science expeditiously executed the search constraint "Timespan: all years". The indices frequently utilised in scholarly investigations comprise SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, and IC.

5. Findings

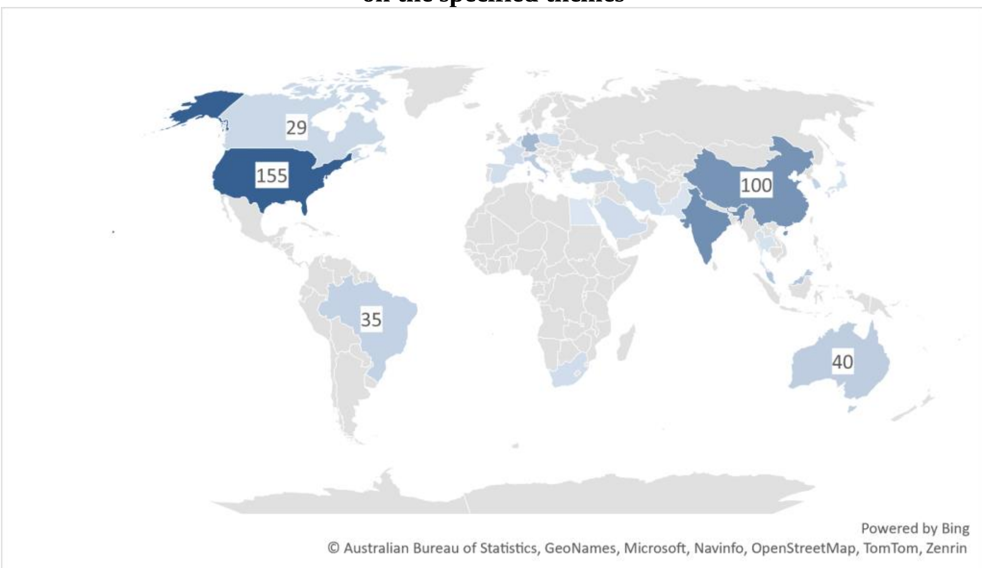
The findings of the investigation indicated a surge in the level of attention towards this subject matter, with the United States, India, Germany, England, and Italy exhibiting the most substantial volume of research in this domain. Utilising the Web of Science database, the study query returned 819 documents published from 1991 to 2023. The prevalent research categories employed for such investigations were Environmental Sciences (22.431 %), Energy Fuels (20.551 %), Green Sustainable Science Technology (18.045 %), Food Science Technology (12.406 %), and Biotechnology Applied Microbiology (10.652 %). The findings indicate a rise in the level of attention towards this particular area. The graphical representation depicted in Figure 4 illustrates the progression in studying the energy and food production sector of scientific papers that have been both published and indexed, pertaining to the specific topics outlined in the study's query.

Figure 1. Treemap showing the top 10 WoS categories connected with the 819 publications that were detected



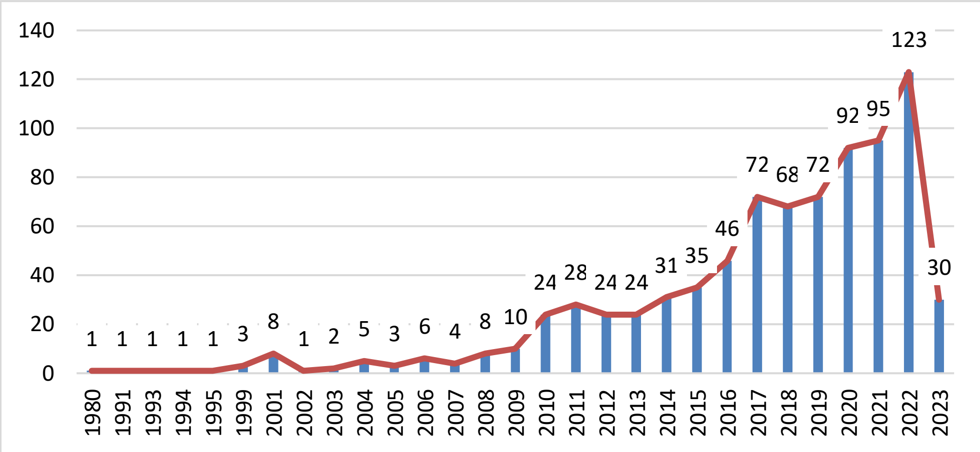
Source: Web of Science.

Figure 2. The origin countries of academics who have disseminated scientific findings on the specified themes



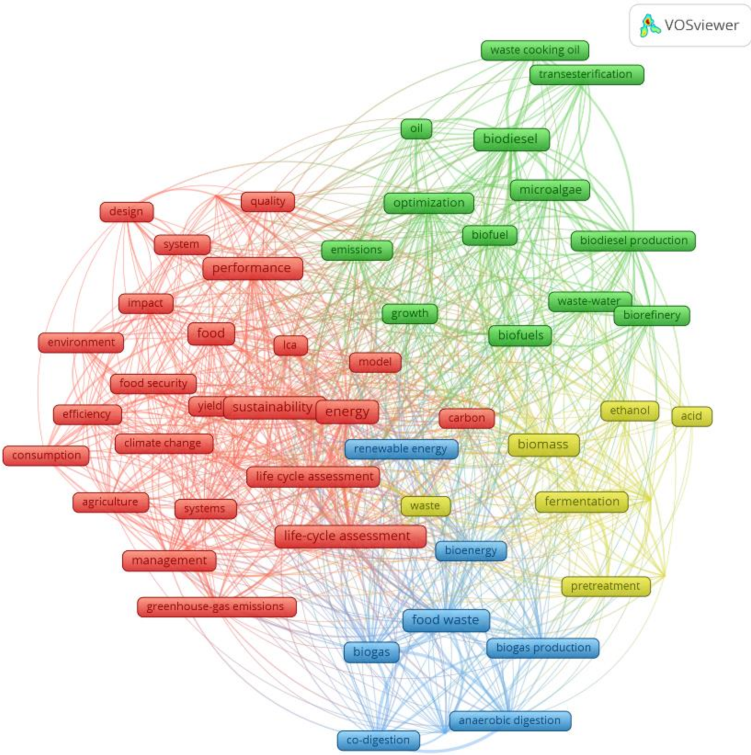
Source: Author's design based on the Web of Science Data.

Figure 3. The evolution of the published and indexed scientific papers approaching the topics specified by the study's query



Source: Author's design based on the Web of Science Data.

Figure 4. Cluster-map analysis of keywords linked to 819 documents identified in Web of Science database



Source: Authors' development in VOSviewer 1.16.16.

The initial cluster of information underscores the formidable obstacles that agriculture encounters as a result of the effects of climate change. Climate change-induced phenomena such as increased temperatures, unpredictable precipitation patterns, and a higher frequency of severe weather events have the potential to impede agricultural productivity in select regions and exacerbate the challenges associated with sustainable farming practices. Paradoxically, the agricultural sector is a significant contributor to climate change due to its involvement in practices such as livestock husbandry, deforestation, and the imprudent application of fertilisers, which can result in the unregulated release of substantial amounts of greenhouse gases. This cluster highlights the necessity of tackling these two-fold challenges in order to attain a food system that is sustainable. Furthermore, the inclusion of the term "consumption" within the aforementioned cluster has prompted the consideration of sustainable consumption models within the realm of research. These models provide a viable approach by advocating for strategies that mitigate the ecological footprints of food systems. Organic farming, regenerative farming, agroecology, and permaculture are agricultural practices that place an emphasis on the preservation of biodiversity, the maintenance of soil health, and the conservation of water resources. Through the promotion of local and seasonal agricultural products and the reduction of chemical inputs, sustainable models effectively mitigate carbon gas emissions linked to agricultural activities, thereby facilitating the transition towards a more sustainable food production system. The notion of energy efficiency, as identified through the cluster analysis, is of significant importance in establishing a sustainable agriculture industry, given the interdependence of food, water, and energy resources. Effective management of energy consumption in agricultural practices, including irrigation, machinery, and processing activities, can substantially alleviate the adverse impacts of greenhouse gas emissions. The incorporation of renewable energy sources, such as solar, water, and wind power, can enhance sustainability in crucial economic sectors by reducing dependence on non-renewable energy sources. This integration also promotes resilience throughout the nexus. As evidenced by the bibliometric analysis cluster, guaranteeing "food security" is a crucial element of this association, given that climate change endangers food production systems by potentially diminishing crop yields and disrupting customary growing seasons. The existing literature indicates that sustainable agricultural practices are crucial to reducing risks and enhancing food security in the context of changing climatic conditions, thereby adding coherence to the preceding arguments. The interconnection among agriculture, climate change, sustainable consumption patterns, energy efficiency, food security, management, and performance, as depicted by the cluster analysis, is a complex network that necessitates collaborative endeavours from both academics and professionals to construct a sustainable future. The establishment of a sustainable food system that is both resilient and environmentally friendly can be achieved through the integration of sustainable practices into daily activities, the enhancement of energy efficiency, the assurance of food security, and the implementation of efficient food management strategies. This system is designed to withstand the contemporary and challenging impacts of climate change.

6. Conclusions

The findings of this research indicate a significant correlation between energy consumption in the agricultural sector and food production. The interdependence between agricultural energy consumption and food production is evident. Therefore, it is imperative to devise and execute strategies that can proficiently regulate energy consumption in agriculture and its consequential impacts on food production. The research outcomes indicate that the implementation of energy-efficient methodologies and technologies in agricultural production is imperative. In addition, efforts should be made to curtail the intensity of energy of agricultural activities. Furthermore, it is crucial to take into account the complete energy system to discern plausible avenues for mitigating energy consumption and its consequential effects on food production. Furthermore, the present investigation has demonstrated the necessity to improve the surveillance and documentation of energy consumption within the agricultural sector. To expand on this point, additional investigation is required to gain a deeper comprehension of the impacts of energy consumption in the agricultural sector on food output, and to formulate more efficient approaches for regulating energy consumption in agricultural production.

In summary, this research has yielded significant findings regarding the correlation between energy consumption in the agricultural sector and the production of food. The aforementioned data can be used to make informed decisions regarding energy consumption in the agricultural sector and its consequential effects on food production. Moreover, the findings of this investigation furnish a robust foundation for further scholarly inquiry into this significant subject matter.

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