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USE OF TECHNOLOGY FOR SUSTAINABLE LIVESTOCK PROCESSES: A BIBLIOMETRIC REVIEW

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ABSTRACT

To this date, livestock activity continues to constitute one of the main bastions of the world economy and global food security. Still, just as it is vital for the subsistence of humanity, it also generates environmental and health effects that deserve attention, and that forge the irrevocable need to look for all possible alternatives to guarantee the sustainability of animal production processes. Therefore, this research has been developed under the framework of a review of the scientific literature related to the use of technology to develop sustainable livestock production processes. This review consisted of a bibliometric analysis developed within the Scopus database, delimiting all the documents published between 1987 and 2023, based on the keywords: "Sustainability", "Livestock" and "Technology", from which the data was obtained, using the search equation (TITLE-ABS-KEY ("sustainability") AND TITLE-ABS-KEY ("livestock") OR TITLE-ABS-KEY ("cattle breeding") OR TITLE-ABS-KEY ("cattle raising") OR TITLE-ABS -KEY ("cattle") AND TITLE-ABS-KEY ("technology")). A total of 887 papers in all were discovered as a consequence, with journal articles accounting for 59% of them, reviews for 19%, conference articles for 11%, and other formats for the remaining 11%. The scientific output examined between 1987 and 2023 demonstrates an increasing tendency in the study area, with the years 2019 to 2022 exhibiting the biggest publishing peaks (47% of all published papers). The findings indicate that 60% of the papers produced for the study subject were published in the United States, the United Kingdom, India, Australia and Italy. Furthermore, Sustainability (Switzerland), Animal, Journal of Animal Science, Journal of Cleaner Production and IOP Conference Series: Earth and Environmental Science, were the journals that published the most on the topic, accounting for 13% of the total publications. The remaining publications are distributed among various journals. Considering that 92% of researchers in this subject are temporary, Koziel JA is the author with the most publications with seven. Similarly, Wageningen University and Research, Iowa State University, Empresa Brasileira de Pesquisa Agropecuária - Embrapa, University of Guelph and Università Degli Studi di Milano were the institutions that conducted the most research on the study's subject, accounting for 11% of the publications.

Key words: livestock, sustainability, cattle raising, cattle breeding, cattle, technology, health, environment

INTRODUCTION

Animal production and especially livestock farming, plays a fundamental role in the world economy, providing food, jobs and livelihoods to millions of people around the world [1]. However, for decades the multiple challenges associated with the environment, public health and animal welfare that each of the activities involved in livestock farming entail have been studied [2]. To face these challenges, there is a growing interest in promoting and developing new technologies that allow adopting truly sustainable animal production practices [3].

Getting into the matter, one of the main global damages generated by the livestock industry is its contribution to greenhouse gas emissions. The Food and Agriculture Organization (FAO) reports that 14.5% of greenhouse gas emissions worldwide are attributable to the production of cattle, mainly through enteric fermentation, manure management and the production of fodder [4]. This effect is expected to continue to increase in parallel with the demand for animal products, which in turn corresponds to the increase in world population, especially in developing countries. Thus, it's critical to adopt sustainable livestock practices that lower greenhouse gas emissions in order to lessen the agricultural sector's contribution to climate change [5].

Another essential aspect to take into account for the development of sustainable livestock is animal welfare. Traditional farming practices are often associated with animals in poor living conditions, threatening animal health and welfare [6]. For example, overcrowding, inadequate housing and a lack of veterinary care can lead to stress, disease and mortality. In response to this, practices aimed at ensuring livestock welfare significantly impact animal health, productivity and product quality [7]. In view of the success in achieving earlier time processes, new technologies play a key role in improving efficiency, reducing greenhouse gas emissions and guaranteeing animal welfare. A clear example of this is Precision Livestock Farming (PLF) which constitutes a differential tool in livestock management and monitoring processes, allowing a more effective execution through the collection and analysis of data related to behavior, health and animal production [8]. According to specialized researchers, these data can be used to optimize feed management, detect diseases early and improve animal welfare. Precision Livestock Farming technologies can also reduce the environmental impact of livestock production by minimizing waste, reducing emissions and improving feed conversion efficiency [9].

Parallel to the PLF technologies, there are other technologies whose relevance is becoming increasingly accentuated at a global level that can also contribute to sustainable animal production. Two clear examples of this are; genetic engineering

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and biotechnology. In the case of genetic engineering, it can help to breed cattle that are more resistant to environmental stress, require less feed and have less environmental impact [10]. On the biotechnology side, within which we can find feed additives, probiotics and vaccines, it can also contribute to improving animal health, reducing greenhouse gas emissions and improving product quality [11]. In general, adopting new technologies in livestock production is the most direct path to more sustainable and efficient processes. As the demand for animal products continues to increase, it is critical to invest in sustainable animal production processes that can meet this demand while minimizing the impact on the environment and animal welfare [12].

Based on this conceptual framework, the study intends to conduct a bibliometric review and analysis, with a particular focus on researching and evaluating scientific output in the form of written products, including books, book chapters, and scientific articles, in order to characterize patterns and information accessibility regarding the advancement and application of technology in global sustainable livestock production. Data from this bibliometric review represents a worldwide diagnosis of the state of knowledge regarding animal production and the potential for insurance as an economic activity and means of subsistence at a global scale. The data generated from this review is aimed to support the advancement of science, new technologies, and methods for the future implementation of solutions similar to the ones described in the preceding paragraphs.

METHODOLOGY

Using the terms "Sustainability," "Livestock," and "Technology," a thorough search of the relevant literature was conducted in the Scopus database in April 2023. The standardization of the keywords is seen in table 1.

The search equation in Scopus was: (TITLE-ABS-KEY (“sustainability") AND TITLE-ABS-KEY ("livestock") OR TITLE-ABS-KEY ("cattle breeding") OR TITLE-ABS-KEY ("cattle raising") OR TITLE-ABS-KEY ("cattle") AND TITLE-ABS-KEY ("technology")); Through this search strategy, 887 documents related to the research topic were recovered, covering a period of time from 1987 to 2023. The information was analyzed using the Microsoft Office Excel program, the R software Bibliometrix package and the VOSviewer tool. The CSV format of the findings was exported from Scopus. Table 2 displays the overall data of the published articles, from which various indicators were developed to examine the quantity, nature, and prominence of publications, as well as the authors, institutions, and nations that have produced the greatest publications in the field.

Table 2 displays the primary data from the documents studied. Eight hundred eighty-seven (887) papers were recovered between 1987 and 2023, with articles making up the majority (521), reviews coming in second with 166, and conference articles in third place with 106; together, these three categories of documents account for 89% of all publications.

RESULTS AND DISCUSSION

Laws of bibliometric productivity

The scientific productivity of writers is described in the first place by Lotka's inverse model, which allows us to know which are the elite and transitory authors in a discipline, that is, the majority of authors produce the least amount of scientific production, while a very small number of authors produce most of it [13, 14, 15]. Compliance with Lotka's law is demonstrated in Figure 1 and Table 3, where the authors who contribute the least, amounting to 91.9% of the total, have only published one article, while 8.1% have published two or more. The maximum number of articles an author can publish is seven. This suggests that the majority of publications are the result of scholars conducting brief investigations into the topic of inquiry.

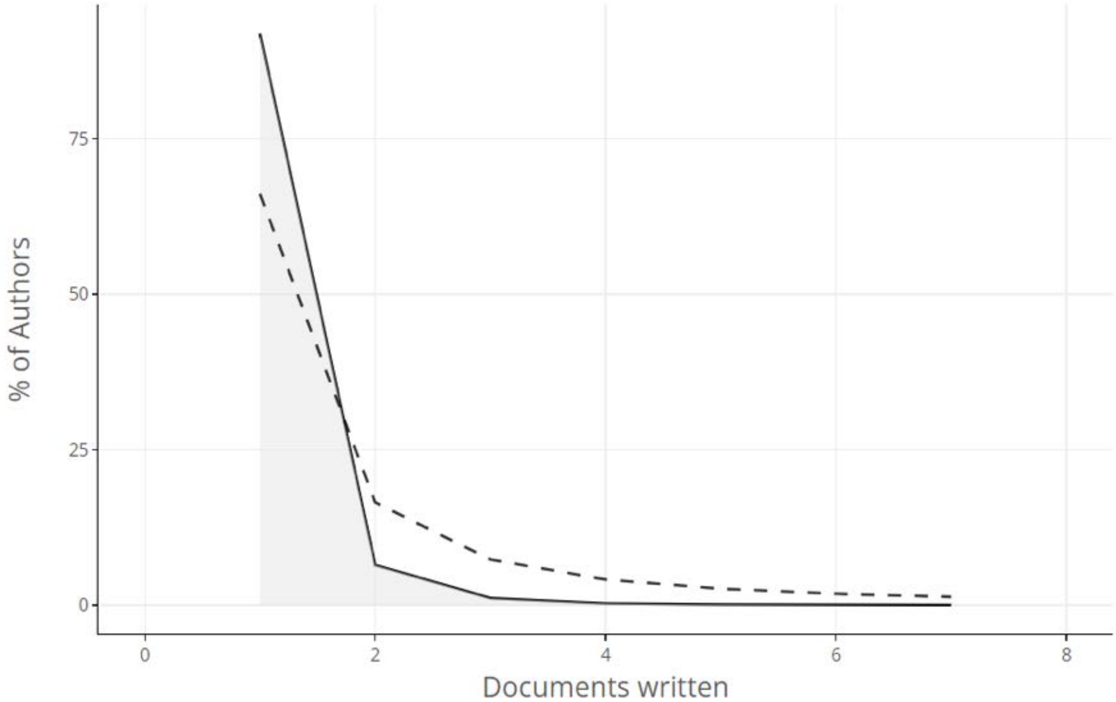

Figure 1: Lotka's Law; source: authors using information from Scopus (2024)

Bradford's law, which is applied to a set of journals to identify the core of the most prolific journals in a particular field and is represented by zones, is also used to determine which of the most productive journals are found in the core. According to Table 4, zone 1 of Bradford's rule, which is where a comparatively small number of highly productive journals are located, is where 33% of published papers are concentrated in the top 32 journals [15, 16]. Of these, the first five journals—

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Sustainability (Switzerland), Animal, Journal of Animal Science, Journal of Cleaner Production, and IOP Conference Series: Earth and Environmental Science—can be highlighted as illustrated in Figure 2, which represents 39% of all publications of the journals that comprise Bradford's zone 1.

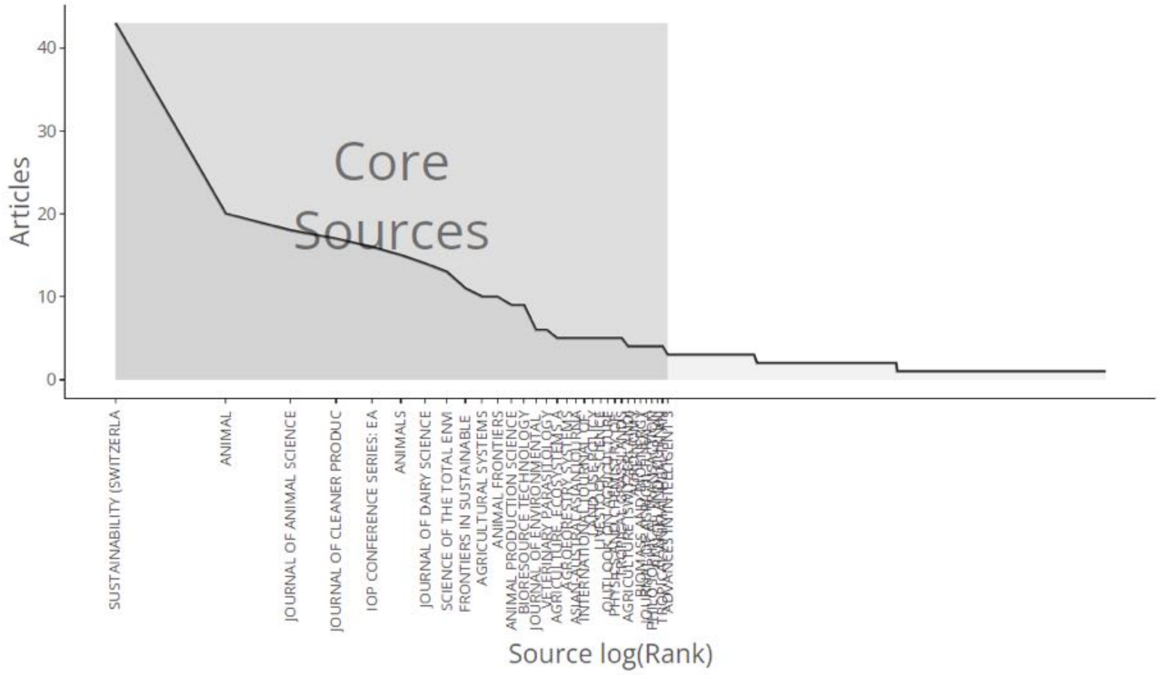

Figure 2: Bradford's Law; source: authors using information from Scopus (2024)

Bibliometric indicators

Figure 3 displays the publications by year. The years 2019 to 2022 are particularly noteworthy because of the significant increase in publications about the research topic during that time, and the fact that 47% of all research is concentrated in this period suggests that the research topic is clearly of interest. It also demonstrates a growing trend in the annual scientific production related to the research topic.

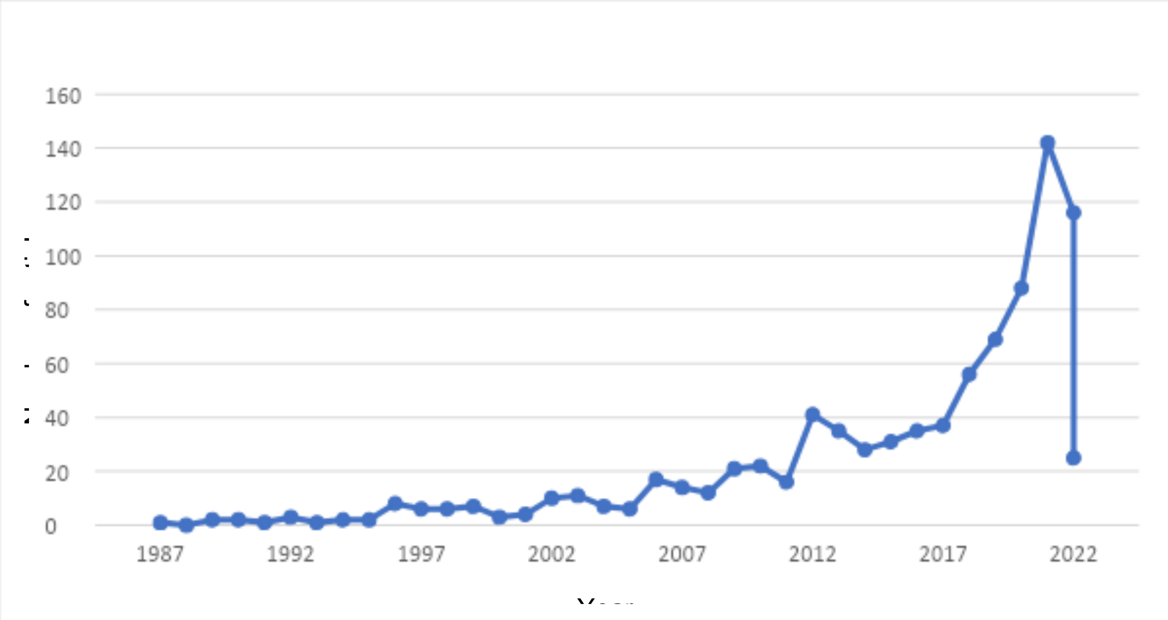

Figure 3: Annual scientific production; source: authors using information from Scopus (2024)

To determine which nations have published the most on the topic, a geographical study was conducted. The countries that contribute the most to the field of study are represented on the map in Figure 4; the United States (194), the United Kingdom (75), India (69), Australia (65) and Italy (63) account for 60% of all publications in the field of study. These countries are also the ones with the darkest blue color in Fig. 4.

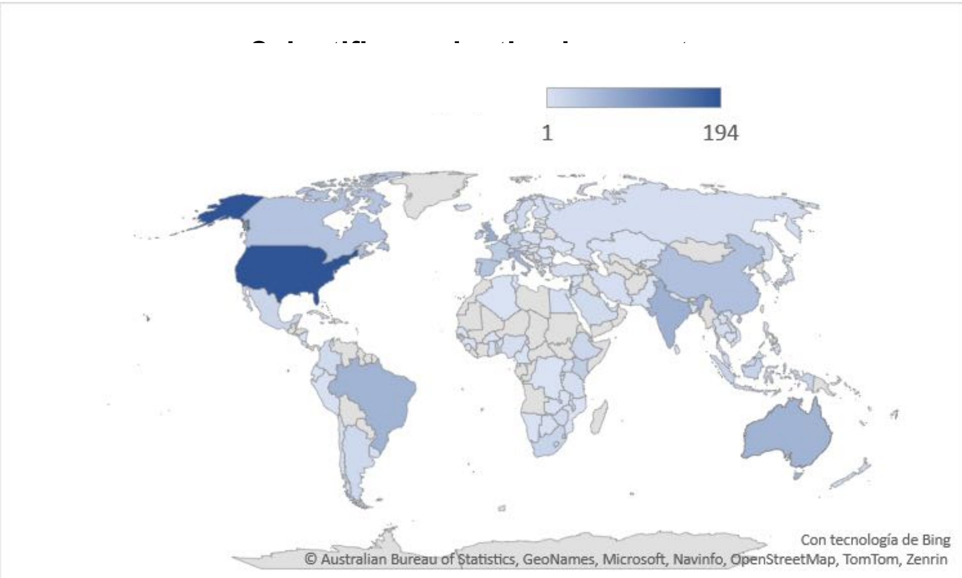

Figure 4: Scientific production by country; source: authors using information from Scopus (2024)

Twenty-two percent of publications are from the United States; one article from this nation discusses how livestock can be sustainably intensified, with an emphasis on cover crops and rotational grazing, which depends on the acceptance and adoption of new practices and technologies [17]. At the same time, other investigations address the development of precision livestock thanks to technological advances, the use of the Internet of Things, global positioning systems and the application of artificial intelligence in areas such as quantity and quality of pasture forage, monitoring one's whereabouts, activity, and behaviors in grazing and foraging situations using devices, measuring one's weight, body composition, physiological evaluations, among others [18, 19].

On the other hand, in the United Kingdom, the research found addresses, among other topics, the raising of farm animals and the use of genome editing technology to create a sustainable food system to achieve the environmental footprint with zero carbon emissions [20]. In this same sense, another article mentions that inherited livestock genetics, precision farming and alternative supply chain options are three promising strategies for dealing with threats to livestock sustainability [21].

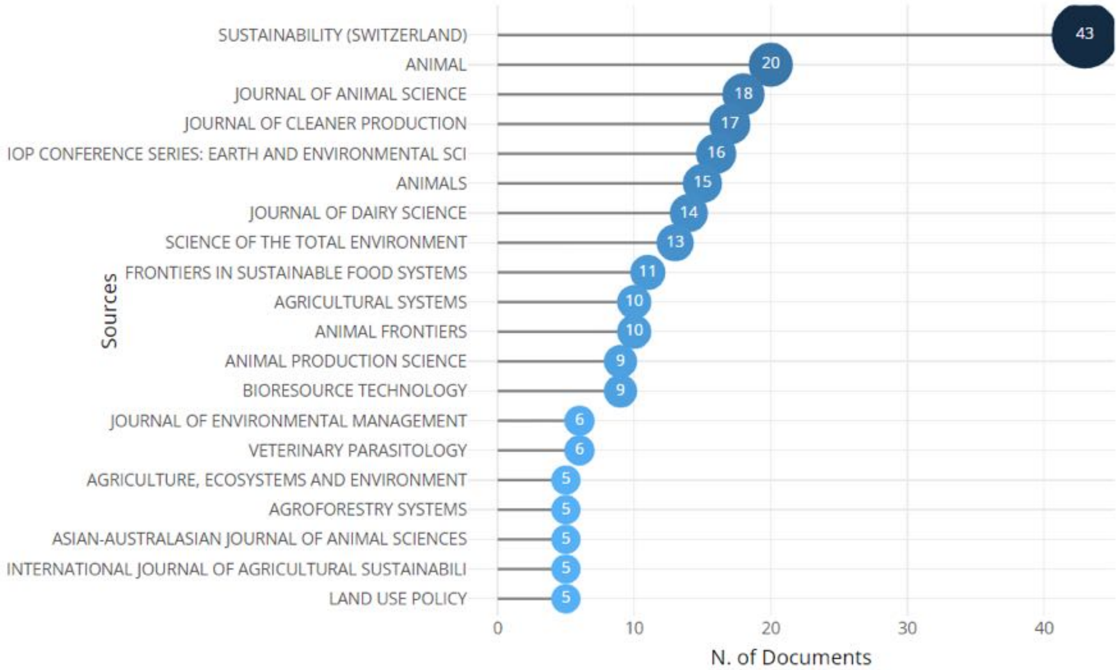

Figure 5: Most relevant sources; source: authors using information from Scopus (2024)

Additionally, a review of the most pertinent literature was done on the subject of the study. According to Figure 5, the four publications that publish the most on the topic are the IOP Conference Series: Earth and Environmental Science (16), Journal of Animal Science (18), Journal of Cleaner Production (17), and

Sustainability (Switzerland) (43). The Brazilian Amazon's initiatives to increase livestock productivity in meat and milk production on over 500,000 hectares of pastures while adhering to the forest code are described in the second most cited article in Sustainability magazine (Switzerland). These initiatives make use of a variety of geographical areas and a wide range of technologies [22]. In addition, in Animal Magazine, the second journal with the most publications, one of the most cited articles is aimed at the sustainability of the beef industry, which requires high efficiency and productivity on farms and efficient value chains; Extensive beef production systems can be given strategic nutritional supplements to overcome deficiencies in the quantity and quality of pasture-based or forage-based feeds [23]. In keeping with this, another research that was located examines the grazing of cover crops in integrated cropping systems and assesses how livestock grazing affects annual ryegrass primary and secondary production in an integrated ryegrass-soybean rotation system. The findings validate the theory that employing ryegrass as a cover crop and fodder has complementary benefits [24].

In comparison to the total number of papers produced between 1987 and 2023, the production per author is low. Figure 6 illustrates that, with seven postings, Koziel J.A. is the author with the most published articles. Koziel JA discusses gas emissions in his most often referenced paper. Gas emissions are a byproduct of raising cattle and poultry, and using cutting-edge oxidation systems on farms can help reduce them. An example of this is ultraviolet A rays which can potentially be used to mitigate certain odorous gases [25]. Figure 7, on the other hand, displays the 10 universities that have published the greatest amount of research on the subject of study. These include the five most significant institutions: Wageningen University and Research, Iowa State University, Empresa Brasileira de Pesquisa Agropecuária – Embrapa, University of Guelph and Università Degli Studi di Milano.

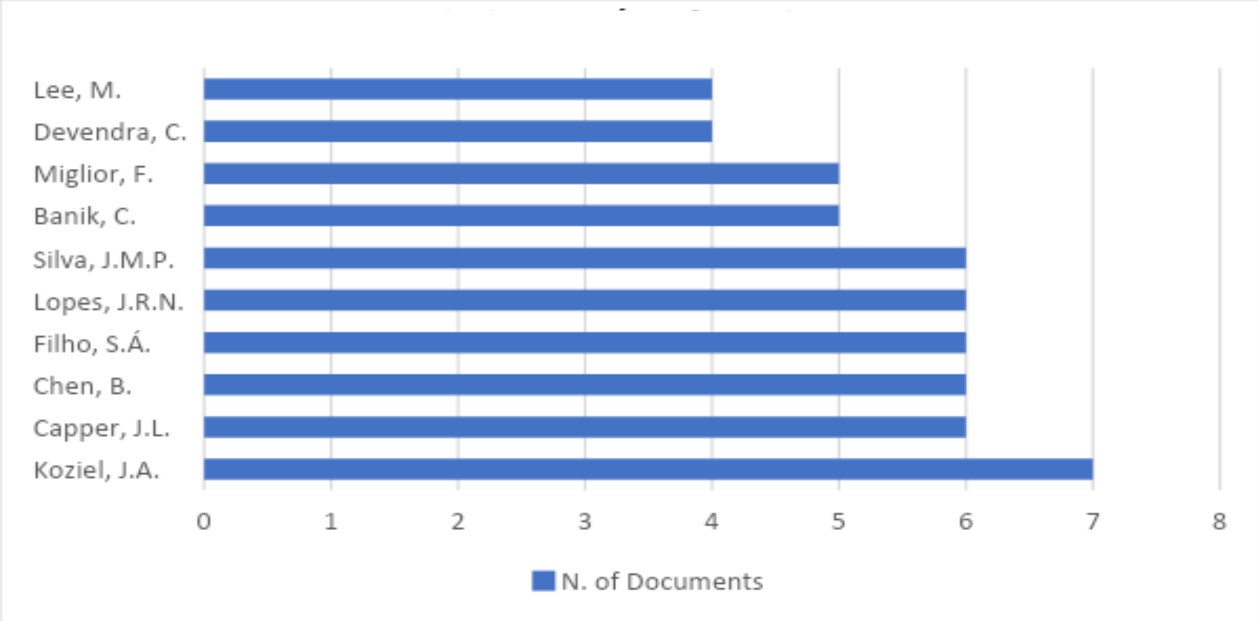

Figure 6: Most relevant authors; source: authors using information from Scopus (2024)

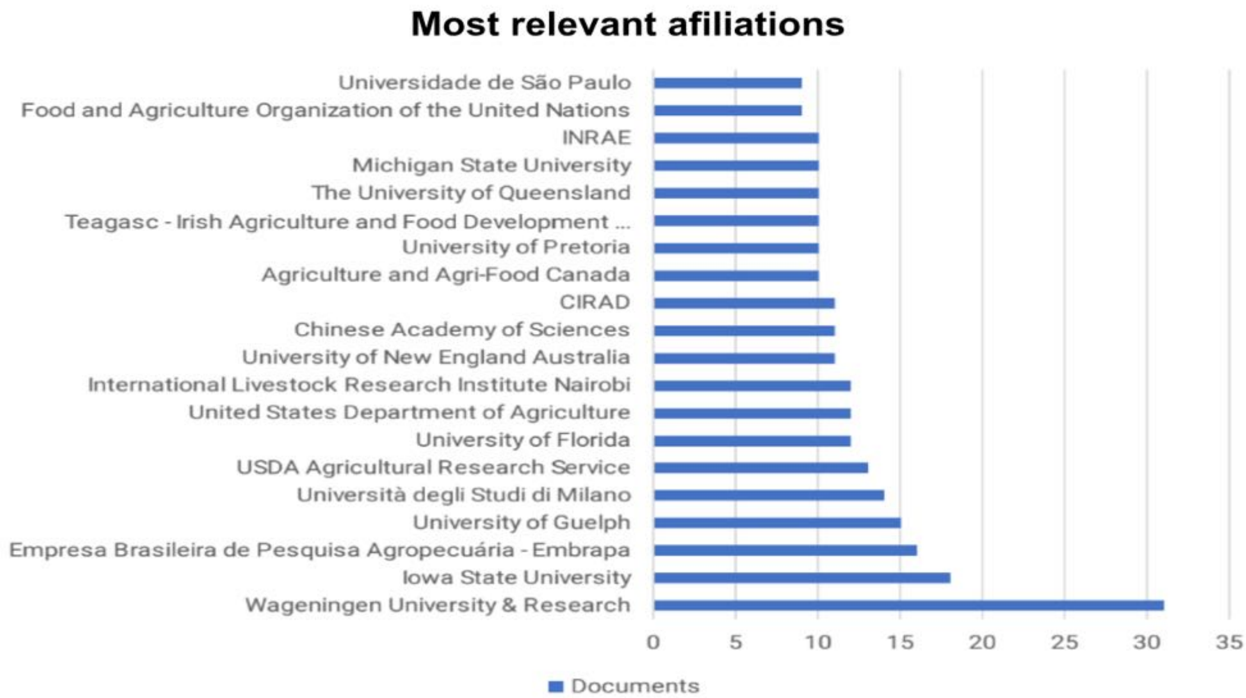

Figure 7: Most relevant affiliations; source: authors using information from Scopus (2024)

Out of the 20 papers in table 5 that have received the most citations, THORNTON PK (2010), PHILOS TRANS R SOC B BIOL SCI, PRETTY J (2008), PHILOS TRANS R SOC B BIOL SCI, GEBBERS R (2010), SCIENCE, and PÖSCHL M (2010), APPL ENERGY are the four most represented. In contrast, Table 6

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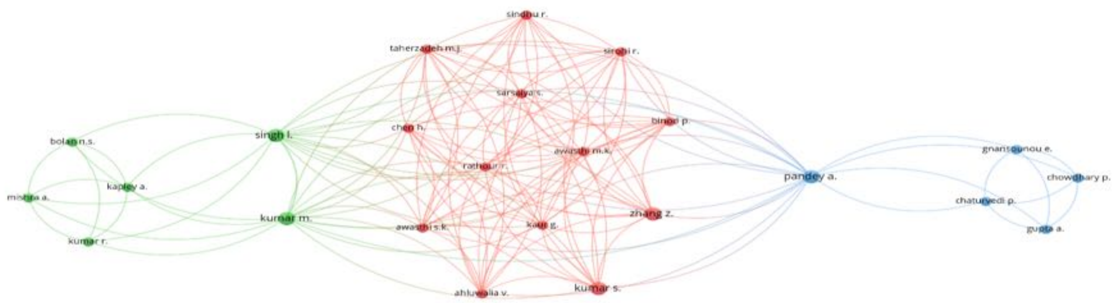
describes the top ten papers that have been referenced in relation to the study subject.

Analysis of Relationships and Co-occurrences

The VOSviewer program is used to analyze correlations and co-occurrences, with the requirement that the author has at least one document and one citation. Of the 855 writers, 694 fit the criteria, according to the co-authorship analysis. Only 24 of these authors—or 3.4% of the total (855)—have co-authored publications, which indicates a relatively low level of author collaboration for the advancement of research on the relevant issue. This can be seen in Figure 7, in which three clusters can be identified.

Ultimately, a co-occurrence analysis of key terms was performed, with the stipulation that a keyword must appear at least five times out of 2578 words. As seen in figures 8 and 9, when 10 clusters are detected, only 107 key words satisfy the criteria. The words sustainability, livestock, food security, agriculture, climate change, environment, precision livestock farming and sustainable agriculture have been highlighted.



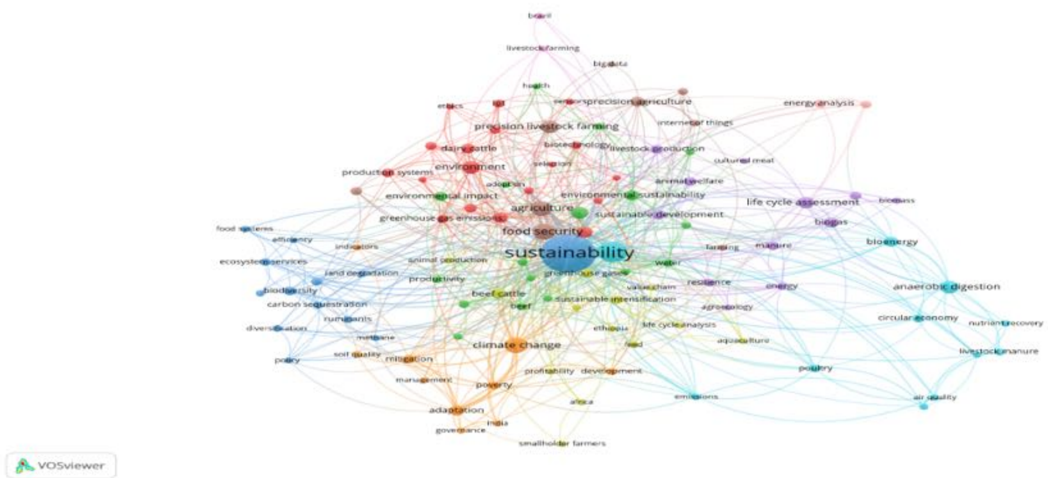


Figure 8: Keyword relationships; source: authors using information from Scopus (2024)

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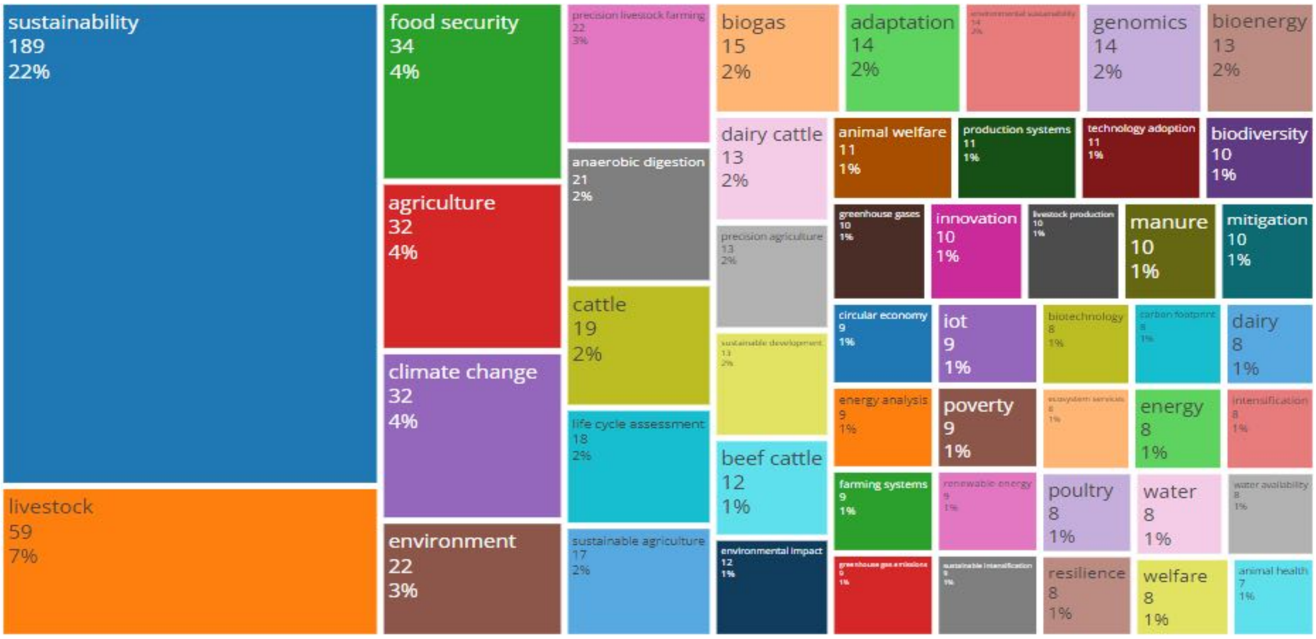

Figure 9: Keyword co-occurrences; source: authors using information from Scopus (2024)

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The following conclusions can be drawn from the 887 documents that were examined for this bibliometric study on the application of technology for sustainable livestock processes using Scopus data: journal articles made up 59% of the documents consulted, reviews made up 19%, conference articles made up 11%, and other formats made up the remaining 11%. A developing tendency in the study topic is evident in the scientific production evaluated from 1987 to 2023; the biggest peak of publications occurred between 2019 and 2022, when 47% of all published papers were gathered. With 60% of the articles published on the study topic, the most productive nations were the US, the UK, India, Australia, and Italy.

Furthermore, Sustainability (Switzerland), Animal, Journal of Animal Science, Journal of Cleaner Production, and IOP Conference Series: Earth and Environmental Science are the journals that publish the most on the topic, accounting for 13% of the total publications; the remaining publications are distributed among various journals. With seven publications, Koziel J.A. was the author with the most published number of papers, however it should be noted that 92% of researchers in this subject are also temporary. Wageningen University and Research, Iowa State University, Empresa Brasileira de Pesquisa Agropecuária – Embrapa, University of Guelph, and Università Degli Studi di Milano are the institutions that do the most research on the topic of study, accounting for 11% of all publications.

To sum up, this study emphasizes how crucial it is to acknowledge the implementation of sustainable livestock practices that leverage technology as an unchangeable source of major advantages for the environment, animal welfare, food safety, and economic growth over the short, medium, and long terms. These advantages can be attained by genetic technologies, biotechnologies, precision agricultural technologies, and other advancements, as this paper's introduction has previously mentioned.

However, adopting these technologies will require collaboration, partnerships and innovation across the entire value chain. In light of all of this, it is hoped that this work will help to fully understand the state of knowledge currently held about the subject and will act as a platform for connecting the findings of various studies conducted in this field. The ultimate goal is to consider and develop solutions that cut across national boundaries and have a substantial impact on livestock production and its effects on the environment and human health on a global scale.

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Table 1: Keyword standardization

Key words	Descriptors
Sustainability	* Sustainability
Livestock	* Cattle breeding * Cattle raising * Cattle
Technology	* Technology

Table 2: Main information of the data obtained from Scopus

MAIN INFORMATION ABOUT DATA	
Timespan	1987:2023
Sources (Journals, Books, etc.)	501
Documents	887
Average years from publication	7,23
Average citations per document	24,64
Average citations per year per doc	3,069
References	48762
DOCUMENT TYPES	
Article	521
Book	5
book chapter	76
conference paper	106
conference review	5
Editorial	3
Note	4
Review	166
short survey	1
DOCUMENT CONTENTS	
Keywords Plus (ID)	0
Author's Keywords (DE)	2578
AUTHORS	
Authors	3311
Author Appearances	3668
Authors of single-authored documents	111
Authors of multi-authored documents	3200
AUTHORS' COLLABORATION	
Single-authored documents	123
Documents per Author	0,268
Authors per Document	3,73
Co-Authors per Documents	4,14
Collaboration Index	4,22

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Table 3: Lotka's Law

Written documents	Number of Authors	Ratio of authors
1	3042	0,919
2	214	0,065
3	37	0,011
4	9	0,003
5	4	0,001
6	4	0,001
7	1	0,0003

Table 4: Bradford's Law

Zone	No. Journals	No. Titles	Percentages
Zone 1	32	293	33,03%
Zone 2	177	302	34,05%
Zone 3	292	292	32,92%

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Table 5: Most cited articles

Articles; DOI	Total Citations
THORNTON PK, 2010, PHILOS TRANS R SOC B BIOL SCI; 10.1098/rstb.2010.0134	1210
PRETTY J, 2008, PHILOS TRANS R SOC B BIOL SCI; 10.1098/rstb.2007.2163	961
GEBBERS R, 2010, SCIENCE; 10.1126/science.1183899	699
PÖSCHL M, 2010, APPL ENERGY; 10.1016/j.apenergy.2010.05.011	604
KNAPP JR, 2014, J DAIRY SCI; 10.3168/jds.2013-7234	529
LEMAIRE G, 2014, AGRIC ECOSYST ENVIRON; 10.1016/j.agee.2013.08.009	420
SMITH P, 2007, AGRIC ECOSYST ENVIRON; 10.1016/j.agee.2006.06.006	415
GODFRAY HCJ, 2010, PHILOS TRANS R SOC B BIOL SCI; 10.1098/rstb.2010.0180	406
BORREANI G, 2018, J DAIRY SCI; 10.3168/jds.2017-13837	327
BEDDINGTON J, 2010, PHILOS TRANS R SOC B BIOL SCI; 10.1098/rstb.2009.0201	281
MCDERMOTT JJ, 2010, LIVEST SCI; 10.1016/j.livsci.2010.02.014	247
MADEIRA MS, 2017, LIVEST SCI; 10.1016/j.livsci.2017.09.020	226
HURNI H, 1993; 10.1017/cbo9780511735394.004	213
GOVAERTS B, 2005, FIELD CROPS RES; 10.1016/j.fcr.2004.11.003	190
RAMACHANDRA TV, 2007, RENEWABLE SUSTAINABLE ENERGY REV; 10.1016/j.rser.2005.12.002	178
POESCHL M, 2012, J CLEAN PROD; 10.1016/j.jclepro.2011.10.030	175
UDOMKUN P, 2017, FOOD CONTROL; 10.1016/j.foodcont.2017.01.008	172
POST MJ, 2014, J SCI FOOD AGRIC; 10.1002/jsfa.6474	169
MACEDO MCM, 2009, REV BRAS ZOOTEC; 10.1590/S1516-35982009001300015	160
CERQUEIRA LEITE RCD, 2009, ENERGY; 10.1016/j.energy.2008.11.001	158

Table 6: Highlights of the ten most cited articles

Highlight	Year	Source	Cite
Analysis of future trends and prospects for livestock production, the livestock sector is dynamic and production systems are increasing their efficiency and environmental sustainability.	2010	PHILOS TRANS R SOC B BIOL SCI	[26]
Analysis of agricultural sustainability that is positive for food productivity, reduced use of pesticides and carbon balances.	2008	PHILOS TRANS R SOC B BIOL SCI	[27]
Relationship between precision agriculture and food safety, considering that adapting production inputs to the specific conditions of each field and each animal allows a better use of resources to maintain the quality of the environment and improve the sustainability of food supply.	2010	SCIENCE	[28]
Evaluation of the energy efficiency of different biogas systems and waste stream management strategies.	2010	APPL ENERGY	[29]
Evaluation of options that have been shown to mitigate enteric methane emissions from dairy cattle in a quantitative and sustained manner and integrate a focus on genetics, feeding and nutrition, physiology and health.	2014	J DAIRY SCI	[30]
Strategies to achieve synergy between agricultural production and environmental quality. Integrated crop and livestock systems can be key in the ecological intensification necessary to achieve food security and environmental sustainability in the future.	2014	AGRIC ECOSYST ENVIRON	[31]
Analysis of the limitations and obstacles to the implementation of strategies for the mitigation of greenhouse gases in agriculture and how climate and non-climate policies have direct or synergistic effects on the mitigation of greenhouse gas emissions.	2007	AGRIC ECOSYST ENVIRON	[32]
Analysis of the future of the global food system and the main factors affecting it between now and 2050; such as demographic growth, changes in consumption patterns, effects of urbanization on the food system and the importance of understanding income distribution.	2010	PHILOS TRANS R SOC B BIOL SCI	[33]

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Analysis of factors affecting dry matter and quality losses in terms of pre-silage field conditions, silage respiration and temperature, fermentation patterns, mulching methods and silage mulch weight and management of aerobic spoilage; and by reducing losses and increasing the efficiency of the silage process, the sustainability of the livestock production chain is increased.	2018	J DAIRY SCI	[34]
Analysis of the new greener revolution in favor of improving crops, more intelligent use of water and fertilizers, new pesticides and more sustainable livestock and marine production, making use of new technologies.	2010	PHILOS TRANS R SOC B BIOL SCI	[35]

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