Hakan SERİN⁴D Beyza Nur CENGİZ²D Aytekin GÜNLÜ²D

¹Selçuk University, Faculty of Veterinary Medicine, Department of Biostatistics, Konya, Türkiye

²Selçuk University, Faculty of Veterinary Medicine, Department of Animal Health Economics and Management, Konya, Türkiye



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Corresponding author/Sorumlu Yazar: Hakan SERİN E-mail: hakan.461995@gmail.com

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A Bibliometric Analysis on Sustainability in Dairy Farming

Süt Sığırcılığında Sürdürülebilirlik Üzerine Bibliyometrik Bir Analiz

ABSTRACT

Dairy farming is a crucial sector in terms of food security, economic development, and environmental sustainability. However, factors such as climate change, animal welfare, economic pressures, and environmental issues threaten the sustainability of the sector. This study aimed to analyze academic publications on sustainability in dairy farming using bibliometric analysis to determine research trends and gaps in the literature. In this study, 410 articles published between 1992 and 2025 in the Web of Science database were analyzed to identify scientific production trends, leading authors, journals, institutions, and countries in the field of dairy farming sustainability. The analysis results indicate a significant increase in the number of publications since 2017, with an annual growth rate of 6.07%, demonstrating the rising scientific output in this area. Keywords such as "sustainability," "dairy farming," and "economic sustainability" stand out, while Agricultural Systems and the Journal of Cleaner Production are among the leading journals in terms of citations and publications. The findings show that scientific production is geographically concentrated in countries such as the United States, Italy, and the Netherlands. The study reveals that knowledge gaps and regional disparities in the field may present potential research topics for future studies.

Keywords: Bibliometric analysis, dairy farming, economic sustainability, environmental impact, sustainability

ÖΖ

Süt sığırcılığı, gıda güvenliği, ekonomik kalkınma ve çevresel sürdürülebilirlik açısından önemli bir sektördür. Ancak iklim değişikliği, hayvan refahı, ekonomik baskılar ve çevresel sorunlar gibi faktörler sektörün sürdürülebilirliğini tehdit etmektedir. Bu çalışmada, süt sığırcılığında sürdürülebilirlik konusundaki akademik yayınlar bibliyometrik analiz yöntemiyle incelenerek, araştırma eğilimleri ve literatürdeki boşlukların belirlenmesi amaçlanmaktadır. Bu çalışmada, 1992–2025 yılları arasında Web of Science veri tabanında yer alan 410 makale analiz edilerek, süt sığırcılığında sürdürülebilirlik konusundaki bilimsel üretim eğilimleri, önde gelen yazar, dergi, kurum ve ülkeler belirlenmiştir. Analiz sonuçları, 2017 yılından itibaren yayın sayısında belirgin bir artış yaşandığını ve yıllık %6,07'lik büyüme oranıyla bu alanda bilimsel üretimin arttığını göstermektedir. "sustainability", "dairy farming" ve "economic sustainability" gibi anahtar kelimeler öne çıkarken, Agricultural Systems ve Journal of Cleaner Production dergileri atıf ve yayın açısından önde gelen dergilerdir. Bulgular, bilimsel üretimin coğrafi olarak United States, Italy ve Netherlands gibi ülkelerde yoğunlaştığını göstermektedir. Çalışma, alandaki bilgi boşlukları ve bölgesel farkılıkların, gelecekteki araştırmalar için potansiyel çalışma konuları teşkil edebileceğini ortaya koymaktadır.

Anahtar Kelimeler: Bibliyometrik analiz, çevresel etki, ekonomik sürdürebilirlik, süt sığırcılığı

INTRODUCTION

The livestock sector, which holds strategic importance for adequate and balanced nutrition, also has significant economic, social, and biological functions. It plays a critical role in ensuring the growing demand for food security and safety.¹⁻³ Milk and dairy products provide essential nutrients such as iron, sterols, and vitamins necessary for human growth and health, ranking among the world's primary food sources.⁴⁻⁶

Dairy farming is of great importance not only for food production but also for sustainable development. Its economic and sociological importance (such as rural employment, balanced urbanization, and migration) positions the sector as the driving force of animal production. However, global warming and climate change have brought the environmental impacts of dairy farming, particularly ruminant farming, into discussion.⁷⁻¹⁰

The pressures on business revenues, the emergence of animal diseases, concerns related to animal welfare, and environmental issues in the dairy farming sector have increased interest in the concept of sustainability.¹¹ Animal diseases raise treatment costs while negatively affecting milk yield and animal health. Additionally, dairy farming is closely associated with environmental factors such as greenhouse gas emissions, water consumption, and land use. The sustainable management of these factors plays a crucial role in reducing the sector's environmental impact.^{12,13} Sustainable animal production plays a critical role in managing global challenges such as human population growth, food security, climate change, energy consumption, biodiversity, and the environmental impacts of human activities.^{14,15}

In this context, the concept of sustainability in dairy farming is generally addressed through three fundamental dimensions: environmental, economic, and social sustainability.¹⁶⁻¹⁸ Environmental sustainability encompasses factors such as greenhouse gas emissions, water consumption, land use, and biodiversity associated with dairy farming.^{19,20} Economic sustainability includes dairy farms' profitability, financial resilience, and resistance to market fluctuations.^{11,21,22} Social sustainability involves the well-being of individuals engaged in dairy farming, animal welfare and health, and rural development.^{23,24}

In recent years, there has been a significant increase in academic studies on dairy farming and sustainability. Classifying and analyzing these studies within a systematic framework is crucial for identifying research trends in the field. In this regard, bibliometric analysis allows for the quantitative and qualitative examination of publications to evaluate the development of a specific academic field.^{25,26}

Bibliometric analysis is a method utilized to examine academic studies on a particular topic based on factors, such as the number of publications, citation distribution, keywords, geographical distribution of research areas, and author collaborations. This analysis helps understand the evolution of scientific research over time, identify frequently studied topics, and detect gaps in the literature.²⁷

This study aimed to conduct a bibliometric analysis of academic publications on sustainability in dairy farming to evaluate research trends, dominant themes, and geographical distributions.

MATERIALS AND METHODS

Data Source and Research Process

Ethics committee permissions for this study were obtained from Selçuk University Faculty of Veterinary Medicine, Experimental Animal Production and Research Centre Ethics Committee and the study was carried out within the scope of the permission of this committee dated 28/04/2025 and numbered 2025/52. The data source for this bibliometric analysis study was obtained from the Web of Science Core Collection (WoS; New York, USA). WoS serves as a standard tool for a significant portion of citation studies worldwide. Additionally, WoS publishes studies that comply with publication ethics.²⁸

A literature search was conducted on January 8, 2025, using an advanced search strategy. A total of 728 articles in agricultural and veterinary sciences were retrieved using the keywords "sustainability" AND "dairy farm" OR "dairy farming" OR "dairy cattle." The inclusion criteria were "document type: article" and "language: English," which resulted in 570 articles. Upon reviewing the content of the retrieved articles, 160 studies were excluded due to irrelevance to dairy farming sustainability, word similarities, or research on different animal species. After applying all filters, the bibliographic dataset consisted of 410 articles fulfilling the required criteria (Figure 1).



Figure 1. Workflow chart.

The data for this bibliometric analysis were extracted from the WoS using the "Full record and cited references" option in both "plain text" and "bib text" formats. The bibliometric analysis of the data was conducted using the "bibliometrics" package available in the R version 4.2.3 (R Foundation for Statistical Computing, Vienna, Austria) statistical program, along with the Biblioshiny interface and Excel 2022. Biblioshiny is a tool that offers multiple categorization options based on sources, authors, documents, social structure, conceptual structure, and intellectual structure.²⁹

Bibliometric Methodology

Bibliometric analysis is a tool used to measure the scientific output of various academic elements (studies, authors, journals, keywords, institutions, and countries) in a particular field and to visually present their intellectual, social, and conceptual structures.³⁰ Bibliometric analysis consists of two main stages: performance analysis and scientific mapping.³¹ Performance analysis examines the contributions of scientific elements within a field using specific metrics (such as citation count, publication count, and h-index).³² Scientific mapping, on the other hand, visually presents the intellectual and structural networks among scientific elements.³³

RESULTS

General descriptive information about the data obtained from WoS and document types is presented in Table 1. Between 1992 and 2025, a total of 410 studies from 144 different journals were included in the analysis. The total number of authors was 1,539, with 20 single-authored studies and 390 multi-authored studies. The studies in the dataset contained a total of 17,494 references, with an average citation count of 16.11 per article. The bibliographic data included 1,033 keywords plus and 1,295 author keywords. An examination of author collaboration statistics revealed an average of 4.38 co-authors per article, an international co-authorship rate of 32.20%, and a collaboration index of 3.89.

Table 1. General Descriptive Information	
Description	Results
Main Information About Data	
Timespan	1992:2025
Sources (Journals, Books, etc.)	144
Documents	410
Annual growth rate (%)	6.07
Document Average Age	7.65
Average citations per documents	16.11
References	17494
DOCUMENT TYPES	
Article	383
Article; early access	4
Article; proceedings paper	23
Document Contents	
Keywords Plus (ID)	1033
Author's Keywords (DE)	1295
Authors	1539
Authors appearances	1796
Authors of single-authored documents	20
Authors of multi-authored documents	1519
Authors Collaboration	
Single-authored documents	20
Multi-authored documents	390
Authors per document	3.75
Documents per author	0.26
Co-Authors per documents	4.38
Collaboration index	3.89
Author footprint index	0.15
International co-authorships (%)	32.20

The publication trends of studies on sustainability in dairy farming between 1992 and 2025 show a significant increase in the number of articles over the years. The first article on this topic was published in 1992. In 2024, 62 articles were published, marking the highest annual count. The annual growth rate was 6.07%. However, the growth trend was not linear. Until 2016, the average annual number of publications was 5.16, while a sharp increase occurred from 2017 onwards, with a continuing upward trend in publication numbers (Figure 2).



Figure 2. Number of publications by year

A three-field diagram was used to provide a general assessment of publications on sustainability in dairy farming between 1992 and 2025. This diagram visualizes the relationships among three main elements: sources (SO), authors (AU), and keywords (DE). Authors predominantly used keywords such as sustainability, dairy

farming, dairy farm, milk, and environment. The most preferred journal was Agricultural Systems, while leading authors such as Tamburini A. and Sandrucci A. primarily published their studies in the Italian Journal of Animal Science (Figure 3).



Figure 3. Three-field diagram: sources (left), authors (middle), and keywords (right).

According to the findings, articles on sustainability in dairy farming were published in 144 different journals. The top 10 journals in which these articles were published are listed in Table 2. Agricultural Systems (n = 31) and Journal of Cleaner Production (n = 19) were the most productive journals, while Journal of Dairy Science (n = 663) and

Animal (n = 563) were the most highly cited journals. The top 10 journals ranked by h-index accounted for approximately 43% of all publications in this field. The international collaboration rates for these journals exceeded 30%.

Table 2. Top 10 Journals Contributing to Publications on Sustainability in Dairy Farming										
Source	h_index	g_index	m_index	TC	NP	CI	IC (%)	JIF	JIF Quartile	Country
Agricultural Systems	16	24	0.727	611	31	19.71	53.55	6.1	Q1	Switzerland
Journal of Cleaner Production	13	19	0.813	522	19	27.47	33.02	9.8	Q1	USA
Journal of Dairy Science	13	25	0.419	663	26	25.5	31.96	3.7	Q1	USA
Animal	12	20	0.667	563	20	28.15	39.44	4	Q1	England
Sustainability	12	17	1	383	40	9.575	30.63	3.3	Q2	Switzerland
Animals	6	11	0.667	124	16	7.75	31.40	2.7	Q1	Switzerland
Agronomy for Sustainable Development	5	6	0.278	241	6	40.17	50.79	6.4	Q1	France
Ecological Economics	5	5	0.156	305	5	61	41.10	6.6	Q1	Netherlands
International Journal of Agricultural Sustainability	5	6	0.333	88	6	14.67	54.83	3.3	Q1	England
Livestock Science	5	7	0.333	125	7	17.86	34.21	1.8	Q2	Netherlands
NP = number of publications, TC = total citations, CI = citation impact, IC = international collaborations, JIF = journal impact factor.										

The metrics demonstrating the scientific productivity of the top 10 authors in publications on sustainability in dairy farming are provided in Table 3. The h-index of these authors ranged from 3 to 6. De Boer, I.J.M. was the most productive author (n = 7), while Berentsen, P.B.M. had the highest citation count (n = 350). Additionally, Baes, C.F. had the highest citation impact. Among the top 10 authors in this field, four were affiliated with institutions in the Netherlands. According to Lotka's Law, 60% of authors were expected to contribute with one publication, 15%

with two publications, and 7% with three publications.³⁴ However, in this field, 87.4% of authors contributed with one publication, 9.7% with two publications, and 2.1% with three publications, indicating a deviation from Lotka's Law. This discrepancy can be attributed to the fact that 51% of the studies in this field were published within the last five years. Additionally, based on Lotka's Law, authors with more than four publications in this field could be considered core contributors.

Table 3. Top 10 Most Productive Authors							
Author	h_index	g_index	m_index	TC	NP	CI	Country
De Boer, I.J.M.	6	7	0.333	174	7	24.86	Netherlands
Berentsen, P.B.M.	5	5	0.227	350	5	70.00	Netherlands
Sandrucci, A.	4	4	0.235	128	4	32.00	Italy
Tamburini, A.	4	5	0.235	128	5	25.60	Italy
Van Calker, K.J.	4	4	0.182	314	4	78.50	Netherlands
Van Keulen, H.	4	4	0.148	59	4	14.75	Netherlands
Baes, C.F.	3	3	0.333	338	3	112.67	Switzerland
Bava, L.	3	4	0.231	192	4	48.00	Italy
Cabrera, V.E.	3	4	0.143	54	4	13.50	USA
Casey J.	3	3	0.250	67	3	22.33	Belgium
NP= number of publications, TC= total citations, CI= citation impact.							

The top 10 most productive institutions, ranked by the number of publications on sustainability in dairy farming, are listed in Table 4. A total of 592 institutions were identified among the authors, indicating a high level of collaboration among researchers from different institutions. The top two institutions with the highest number of publications were Wageningen University (Netherlands) and the University of Milan (Italy).

Table 4. Top 10 Most Productive Institutions		
Affiliation	Articles	Country
Wageningen University	31	Netherlands
University of Milan	29	Italy
Wageningen University and Research Center	28	Netherlands
Wageningen University and Research	23	Netherlands
University of Guelph	22	Canada
The Swedish University of Agricultural Sciences	18	Sweden
Animal and Grassland Research and Innovation Center	17	Ireland
University of Wisconsin	17	USA
University of Toulouse	16	France
University College Dublin	15	Ireland

From 1992 to 2025, a total of 56 countries contributed to publications on dairy farming sustainability. A heatmap visualized the geographical distribution of publications by country (Figure 3A). The top three countries with the highest number of publications were the United States (n = 45), Italy (n = 44), and the Netherlands (n = 30). Other productive countries included Canada, Brazil, China, and several European countries (Ireland, France, the United

Kingdom, and Spain). Africa, Central and Western Asia, the Caribbean, and Eastern European countries were significantly underrepresented. An analysis of the authors' countries showed that the United States, Italy, and the Netherlands accounted for 29% of the publications in this field. The multiple-country publication (MCP) percentage was used to reflect international collaboration. In leading countries, including the United States, Italy, and the Netherlands, most publications were single-country publications (SCP). Among the top ten most productive countries, only the United Kingdom had an MCP rate exceeding 50% (53.3%) (Figure 3B). Regarding citations, the top five most cited countries were the Netherlands (n = 914), Italy (n = 767), the United States (n = 741), Canada (n = 628), and Belgium (n = 515). In terms of average citations per document, the top five countries were Canada (48.30), Kenya (47.50), Belgium (46.80), the Netherlands (30.50), and New Zealand (23.50) (Figure 3C).



Figure 4. Country production and citation. (A) Heatmap showing the number of publications from different countries based on corresponding authors' affiliations. (B) Countries of corresponding authors, SCP (single-country publication); MCP (multiple-country publication). (C) Most cited countries.

Keyword analysis is essential for identifying research trends in a field. The bibliometric network of the most frequently used keywords is presented in Figure 5. Similar keywords were clustered based on network analysis, forming seven main clusters represented in red, green, yellow, purple, blue, pink, and brown. The keyword network analysis revealed that the terms "sustainability," "economic sustainability," "sustainable agriculture," "dairy farming," and "dairy" were frequently used.



Figure 5. Bibliometric network of the most frequently used keywords.

Table 5 lists the ten most cited references. The study titled "A 100-Year Review: Identification and Genetic Selection of Economically Important Traits in Dairy Cattle" by Miglior F., published in 2017, ranked first with 292 citations, leading both in total citations and annual average citations. The study "MOTIFS: a monitoring tool for integrated farm sustainability" by Meul M., published in 2008, ranked second with 159 citations.

Table 5. Top ten most cited references			
Paper	DOI	TC	TC per Year
Miglior F., 2017, J. Dairy Sci.	10.3168/jds.2017-12968	292	32.44
Meul M., 2008, Agron. Sustain. Dev.	10.1051/agro:2008001	159	8.83
Van Passel S., 2007, Ecol. Econ.	10.1016/j.ecolecon.2006.06.008	144	7.58
De Vries A., 2020, Animal	10.1017/S1751731119003264	130	21.67
Sanderson M.A., 2005, Agron. J.	10.2134/agronj2005.0032	126	6.00
Van Calker K.J., 2005, Agric. Human Values	10.1004/s10460-004-7230-3	118	5.62
Guerci M., 2013, J. Clean. Prod.	10.1016/j.jclepro.2013.04.035	104	8.00
Boichard D., 2012, Animal	10.1017/S1751731112000018	96	6.86
Schuppli C.A., 2014, J. Anim. Sci.	10.2527/jas.2014-7725	92	7.67
Van Calker K.J., 2004, Agric. Syst.	10.1016/j.agsy.2004.02.001	90	4.09
TC= total citations			

DISCUSSION

The analysis results not only demonstrate the increasing scientific productivity in the field of dairy farming sustainability but also highlight significant geographical disparities in research distribution. Notably, a sharp increase in publication numbers after 2017 stands out. The annual growth rate in this field was determined to be 6.07%. In recent years, growing awareness of the environmental

challenges posed by agricultural production, ongoing economic competition affecting farm incomes, and concerns regarding animal welfare have contributed to the rising interest in dairy farming sustainability.¹¹ The implementation of the United Nations Sustainable Development Goals (SDGs) in 2015 has also played a role in increasing attention to this subject.³⁵

An analysis of the literature distribution reveals that the

variation among the top ten contributing journals indicates the multidisciplinary nature of research on dairy farming sustainability. The distribution of authors and collaboration statistics further demonstrate the openness of the field to cooperation. The predominance of multi-author studies over single-author ones and an international collaboration rate of 32.20% suggest a high tendency among researchers from different institutions and regions to share knowledge and expertise. This collaborative approach is a key factor in enhancing scientific productivity and addressing challenges in sustainable dairy farming. The presence of a critical global issue such as climate change encourages researchers to develop joint solutions and promotes interdisciplinary studies.

At the country level, the fact that the majority of publications originate from countries such as the United States, Italy, and the Netherlands indicates that developed countries have a strong interest in and high research capacity for this topic. In the United States, advancements in dairy farm technology and management over the past 50 years have led to increased milk production while reducing environmental impacts.³⁶ Italy's significant role in European dairy production and the European Union's policies promoting sustainable production have contributed to the concentration of research in this area.³⁷ In the Netherlands, the institutionalization of cooperatives, the implementation of the EU's Common Agricultural Policy in the 1960s, regulatory measures, and government support for dairy farming have accelerated sustainability-related research.³⁸ Although two of the top three contributing countries are in Europe, economic sustainability challenges vary across European nations. Countries such as Romania, Lithuania, Croatia, Austria, Poland, and Bulgaria, where small-scale farms are prevalent, have been reported to lag in this area.³⁹ In developing countries, the dairy farming sector faces various structural and economic challenges that threaten sustainability, including financial constraints, insufficient private sector investments, lack of technology and research, and inadequate cold chain and marketing infrastructure.⁴⁰⁻ 42

The United States, Italy, and the Netherlands demonstrate a high level of international collaboration in sustainability studies related to dairy farming. In contrast, studies in Turkiye are mostly conducted at the national level. Citation counts indicate the scientific impact of a country's publications. To enhance the citation impact of sustainability studies in dairy farming in countries like Turkiye, greater international collaboration and publication in high-impact journals are necessary. Studies conducted through international collaborations tend to attract more global attention and receive higher citation counts.^{43,44} Notably, despite a lower number of publications, Kenya stands out with a high citation count. The high average citation rate of studies from Kenya suggests that research conducted in this country is particularly significant for local and regional sustainability practices. Furthermore, the increasing focus on this topic among academic researchers is likely influenced by the tangible effects of climate change in the region.⁴⁵ This finding underscores that a small number of studies can be highly impactful in terms of quality and influence, highlighting the importance of assessing research outputs not only quantitatively but also qualitatively.

Bibliometric network analysis of keywords is crucial for understanding research trends and the conceptual structure of the field. The frequent use of terms such as "sustainability," "economic sustainability," "dairy farming," and "dairy" reflects the core research focus areas. Keyword clusters indicate that researchers approach the topic from different perspectives, such as economic and environmental aspects, pointing to potential research directions for future studies. Douglas et al.³⁵ reported that the term "dairy farming" appears in multiple keyword clusters, emphasizing its central role in the field due to the diverse aspects examined by researchers. Similarly, in this study, the terms "dairy farming" and "dairy cattle" were found in different keyword clusters, indicating that research in the field encompasses the environmental, social, and economic dimensions of dairy farming. Keywords such as "methane," "climate change," "carbon," and "footprint" suggest that the impact of dairy farming on greenhouse gas emissions and climate is a frequent research subject. The term "animal welfare" is also considered a significant component of the social dimension of sustainability in dairy farming. While the dairy sector faces challenges in maintaining a high quality of life, minimizing environmental impact, and ensuring cost-effective production, global climate agreements and consumer expectations regarding dairy production continue to shape research in this field.¹³ A review of the literature reveals that studies integrating all three dimensions of sustainability-environmental, social, and economic—are limited.¹⁷ Life cycle assessment is an recognized method internationally used to comprehensively evaluate the environmental impact of sustainability.⁴⁶ The co-occurrence of the keywords "sustainability," "life cycle assessment," and "dairy cattle" indicates that life cycle assessment is widely utilized in sustainability assessments of dairy farming.

In conclusion, the data obtained indicate that the literature on sustainability in dairy farming is rapidly evolving both quantitatively and qualitatively, with the conceptual and intellectual structure of the field transforming over time. The study's results also highlight knowledge gaps and regional disparities, suggesting potential research areas for future studies. Moreover, bibliometric analysis provides a comprehensive assessment of scientific productivity and collaboration networks, serving as a valuable tool for strategic planning in the development of sustainable dairy farming practices and policies. Researchers interested in this field can enhance their contributions by collaborating with leading countries, regions, and authors and carefully selecting target journals for publication.

The methodological approach of this study, supported by the reliability of the WoS database and advanced bibliometric analysis tools, comprehensively reveals the scientific productivity, collaboration networks, and intellectual structure of the field. However, the study has certain limitations. The inclusion of only English-language publications may have excluded some regional literature from the analysis. Additionally, as the coverage of the WoS database does not encompass all studies available in other databases, the generalizability of the results may be subject to certain constraints.

Ethics Committee Approval: Ethics committee permissions for this study were obtained from Selçuk University Faculty of Veterinary Medicine, Experimental Animal Production and Research Centre Ethics Committee and the study was carried out within the scope of the permission of this committee dated 28/04/2025 and numbered 2025/52.

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