Global Research Trends on Carbon Footprint in Livestock Production: A Bibliometric Analysis

Sevtap Tırınk[1], and Cem Tırınk[2]*

***Abstract*—** The carbon footprint of livestock production has become an increasingly important research area in the context of climate change and sustainable agriculture. Raising greenhouse gas emissions, particularly methane, land use, and feed systems, has positioned the livestock sector as a critical contributor to environmental impacts. Therefore, a systematic understanding of the field's scientific development, thematic structure, and research trends is essential. This study investigates the global scientific landscape of livestock carbon footprint research through a bibliometric analysis of 5,054 publications retrieved from the Web of Science Core Collection, covering 1980–2025. Analyses were conducted using the Bibliometrix package and Biblioshiny interface, incorporating performance indicators, international collaboration networks, co-citation analysis, bibliographic coupling, and keyword-based thematic mapping. The results reveal a stable and accelerating growth trend, with an annual growth rate of 12.42%. The field is highly collaborative, with an international co-authorship rate of 34.63% and an average of 5.69 authors per document. The average citation rate (36.89) indicates strong scientific impact, while publication output has increased markedly since 2010. Science mapping shows that the field is structured around life-cycle assessment, greenhouse gas emissions, and carbon footprint. Leading journals include Journal of Cleaner Production, Sustainability, and Science of the Total Environment, with China, the United States, and European countries as key contributors. Overall, the field remains in an expansion phase, offering significant opportunities for sustainable and data-driven research.

***Keywords*—** Livestock production, Carbon footprint, Greenhouse gas emissions, Life cycle assessment.

I. Introduction

Global environmental challenges, particularly climate change driven by increasing greenhouse gas (GHG) concentrations, have intensified the need for sustainable development strategies worldwide. Among the major contributors to anthropogenic GHG emissions, the agricultural sector plays a critical role, with livestock production recognized as a key source of methane (CH_4) emissions, as well as a driver of land-use change and feed-related impacts on the carbon footprint of food systems. Methane emissions from enteric fermentation, manure management, and manure storage account for a substantial share of agricultural emissions, while land-use demands and feed systems further amplify the overall environmental burden across life-cycle stages [1-3].

Consequently, increasing scientific and policy attention has been directed toward developing sustainable livestock systems that can mitigate environmental impacts while maintaining productivity and animal welfare [4-8].

In this context, research on the carbon footprint of livestock production has evolved into a complex and multidimensional field. It encompasses a wide range of interacting factors, including production systems, feed composition, geographic conditions, climate variability, animal genetics, and management practices, typically evaluated within life cycle assessment (LCA) frameworks [5,6,9]. Moreover, methodological diversity—such as differences in system boundaries, functional units, and analytical approaches—further complicates the comparability and interpretation of results across studies [1,9]. The inherently interdisciplinary nature of the field, integrating animal science, environmental science, agronomy, economics, and data science, has also fostered increasing collaboration among researchers and institutions worldwide [4,10,11].

Over the past decades, the volume of scientific publications on livestock carbon footprint has grown rapidly, reflecting both the increasing availability of environmental data and the rising importance of sustainability in agricultural systems. This expansion has created a rich but complex body of literature, making it increasingly difficult to obtain a comprehensive understanding of the field through traditional narrative reviews alone. Systematic approaches are therefore required to capture how knowledge is produced, how research collaborations evolve, and how thematic priorities shift over time [1, 12-15].

Despite this rapid growth, there remains a significant gap in the literature regarding comprehensive bibliometric analyses that systematically map the global research structure of livestock carbon footprint studies. Existing bibliometric studies in related domains—such as greenhouse gas emissions, food systems, and environmental sustainability—demonstrate the value of science mapping approaches but do not provide an integrated assessment specifically focused on livestock carbon footprint research [4,5, 11, 13, 16-18]. Therefore, a comprehensive and systematic bibliometric investigation is needed to reveal the intellectual structure, collaboration patterns, and emerging research trends within this field.

Bibliometric analysis provides a robust, quantitative framework to address this need by enabling the systematic evaluation of scientific output, knowledge structures, and research dynamics. Through performance analysis and science

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[1]Sevtap Tırınk, Iğdır University, Health Services Vocational School, Department of Medical Services and Techniques, Environmental Health Program, 76000, Iğdır, Türkiye

[2]Cem Tırınk, Iğdır University, Agricultural Faculty, Department of Animal Science, 76000, Iğdır, Türkiye

mapping techniques—such as co-authorship, co-citation, bibliographic coupling, and keyword co-occurrence analysis—it is possible to identify influential contributors, dominant research themes, and evolving trends [3, 13, 14, 15]. In the context of livestock carbon footprint research, these methods offer valuable insights into how scientific knowledge is structured and how it evolves in response to emerging environmental challenges.

In this context, the present study aims to provide a comprehensive bibliometric analysis of global research on carbon footprint in livestock production. Using data retrieved from the Web of Science Core Collection, this study systematically examines the temporal evolution of scientific production, leading countries and institutions, collaboration networks, the field's intellectual structure, and its thematic development. Furthermore, it seeks to identify emerging research directions and key areas requiring further investigation, including sustainable production strategies, emission mitigation approaches, and advancements in LCA methodologies.

By offering an integrated and data-driven overview of the research landscape, this study contributes to a deeper understanding of how knowledge on livestock carbon footprint has evolved over time. The findings are expected to support researchers in situating their work within the global scientific context and to provide valuable insights for policymakers seeking to design effective and sustainable livestock management strategies.

II. Materials And Methods

The bibliometric dataset used in this study was obtained from the Web of Science (WoS) Core Collection, a widely recognized multidisciplinary database frequently used in bibliometric and research evaluation studies for its high indexing standards, transparent selection procedures, and rich citation information [19]. WoS was selected as the primary data source due to its comprehensive and consistent coverage of environmental sciences, agricultural systems, and sustainability-related research areas, which are directly relevant to this study's scope.

All records were retrieved from the WoS Core Collection on 31.03.2026, ensuring the dataset's reproducibility and temporal consistency. The search included all available citation indexes within the Core Collection. Only peer-reviewed research articles and review papers were retained, while other document types, such as conference proceedings, book chapters, editorial materials, notes, and meeting abstracts, were excluded. To maintain dataset consistency, Early Access publications and records assigned to the year 2026 were removed. Although the initial search did not impose language restrictions, only English-language publications were included in the final dataset to ensure uniformity in keyword analysis and thematic interpretation.

To capture the global scientific literature on carbon footprints in livestock production, a Topic Search (TS) approach was employed. The TS field encompasses terms appearing in titles, abstracts, author keywords, and Keywords Plus. Boolean operators were systematically applied to construct a comprehensive and focused search query that includes relevant livestock production systems while excluding unrelated domains. The final search query was defined as follows:

TS= (("carbon footprint" OR "life cycle assessment" OR LCA OR "environmental footprint")

AND (livestock OR "livestock production" OR "livestock system*" OR "animal production" OR "animal husbandry" OR "animal agriculture" OR ruminant* OR cattle OR dairy OR beef OR sheep OR goat* OR poultry OR swine OR pig* OR buffalo*))

NOT TS= ("human diet" OR "dietary carbon footprint" OR "plant-based diet" OR aquaculture OR fishery OR fisheries OR "pet food" OR pets OR "wild animals")

This search strategy ensured a broad yet precise coverage of livestock-related carbon footprint research while excluding studies focusing on human diets, aquaculture, fisheries, and non-livestock animal systems.

A bibliometric framework was applied to analyze the evolution, structure, and knowledge dynamics of research on carbon footprint in livestock production. Bibliometric methods provide a systematic and quantitative approach to evaluate scientific output, research impact, and collaboration structures within a specific domain [19, 20].

The analyses were carried out using the Bibliometrix package in R (version 2025.09.2) along with its web-based interface Biblioshiny, which enables comprehensive data processing, visualization, and network analysis [21, 22]. The methodological approach followed established bibliometric procedures and consisted of two main components: performance analysis and science mapping.

III. RESULTS And Discussion

Figure 1 provides a comprehensive overview of the main bibliometric characteristics of the dataset obtained from the Web of Science Core Collection. This figure summarizes key indicators, including temporal coverage, publication output, citation impact, and collaboration patterns, providing a general framework for understanding the structure and development of research on the carbon footprint in livestock production. Overall, it establishes the basis for interpreting publication trends, authorship structures, international collaboration, and the field's thematic scope.

The dataset covers the period from 1980 to 2025 and includes 5,054 publications distributed across 1,157 sources, highlighting the interdisciplinary nature of research at the intersection of livestock production, environmental science, and sustainability studies. The observed annual growth rate of 12.42% indicates a steadily expanding research domain, particularly in recent decades, reflecting the increasing global concern over greenhouse gas emissions and the environmental impacts of livestock systems.

Authorship analysis indicates contributions from approximately 20,800 researchers, with a relatively low

proportion of single-authored studies, underscoring the field's collaborative nature. The average of 5.69 co-authors per document and an international co-authorship rate of 34.63% demonstrate the importance of cross-institutional and cross-national collaborations in addressing complex environmental challenges associated with livestock production. Furthermore, the relatively high average number of citations per document (36.89) and a mean document age of 7.35 years indicate both strong scientific impact and sustained relevance of the research output.

Fig 1. Main bibliometric indicators of the dataset retrieved from the Web of Science Core Collection (1980–2025).

Figure 2 illustrates the annual scientific output of studies on the carbon footprint in livestock production over the analyzed period. The temporal distribution reveals an extended initial phase characterized by relatively low, stable publication output, followed by a marked, continuous increase in research activity, especially after 2010.

Between 1980 and the early 2000s, the number of publications remained limited, reflecting the early stage of research development, during which the environmental impacts of livestock production were explored in a more fragmented and less systematic manner. This phase reflects the gradual emergence of life cycle assessment approaches and growing awareness of greenhouse gas emissions in agricultural systems.

A noticeable upward trend becomes evident after the mid-2000s, with a significant acceleration observed from 2010 onwards. This rapid increase coincides with heightened global attention to climate change, advancements in environmental assessment methodologies, and the expansion of sustainability-oriented research. The sharp growth in recent years highlights the growing importance of carbon footprint assessment in livestock systems, particularly regarding emission mitigation strategies, sustainable production practices, and policy-driven research initiatives.

Overall, the publication trend presented in Figure 2 indicates that research on carbon footprint in livestock production has evolved from a relatively niche topic into a rapidly expanding and increasingly mature research field. This consistent upward trajectory provides a solid empirical foundation for further analyses of the field's structural characteristics, collaboration networks, and thematic evolution.

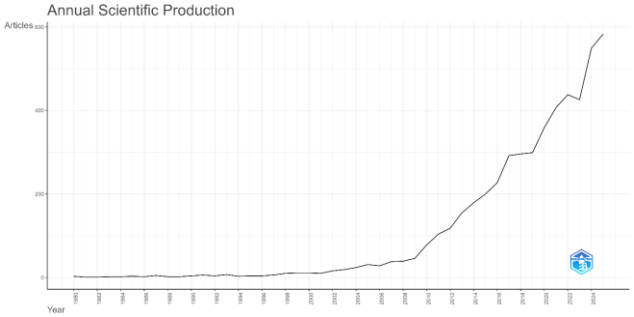

Fig 2. Annual scientific production of publications on carbon footprint in livestock production (1980–2025).

Figure 3 presents a three-field plot illustrating the relationships among countries (AU_CO), sources (SO), and author keywords (ID) within the research field of carbon footprint in livestock production. This visualization provides an integrated perspective on how scientific production, publication outlets, and thematic focus areas are interconnected, thereby revealing the structural composition of the research domain.

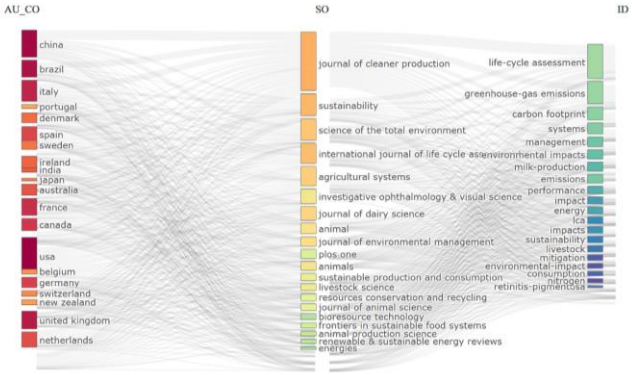

Fig 3. Three-field plot showing the relationships between countries, sources, and keywords in the research field.

The country-level distribution highlights China, the United States, and several European countries, including Italy, Spain, and the United Kingdom, as leading contributors to the field. These countries occupy central positions within the network, indicating both high publication productivity and strong linkages with influential journals and key research themes. The prominence of these countries reflects their substantial investment in environmental research, sustainability initiatives, and livestock production systems.

In terms of sources, journals such as the Journal of Cleaner Production, Sustainability, Science of the Total Environment, and the International Journal of Life Cycle Assessment emerge as the most prominent outlets. These journals serve as major platforms for knowledge dissemination, bridging research outputs from different countries across core thematic areas. Their central position in the network suggests they play a pivotal role in shaping scientific discourse on the livestock-related carbon footprint and sustainability.

The keyword dimension reveals that the field's intellectual focus is strongly centered on terms such as "life cycle assessment," "greenhouse gas emissions," and "carbon

footprint." These core themes are closely linked to applied concepts including "production systems," "environmental impacts," "milk production," "energy," and "sustainability." The presence of these interconnected keywords indicates that research in this field is largely driven by efforts to quantify environmental impacts and develop strategies for emission reduction and sustainable livestock management.

Furthermore, the dense connections between countries, journals, and keywords demonstrate a high level of integration within the research field. This interconnected structure suggests that knowledge production is not isolated but shaped by continuous interactions among geographic regions, publication platforms, and thematic developments.

Overall, Figure 3 highlights a well-structured and globally interconnected research landscape, where leading countries, influential journals, and core thematic areas collectively drive the advancement of knowledge on carbon footprint in livestock production. This integrated structure supports the diffusion of methodologies such as life cycle assessment and facilitates the development of globally relevant sustainability strategies.

Fig 4. Word cloud visualization of the most frequently occurring keywords in research on carbon footprint in livestock production, highlighting the dominant thematic focus of the field.

The overall thematic structure of the research field is further illustrated in Figure 4, which presents a word cloud of the most frequently used keywords. This visualization highlights the prominence of core concepts such as life cycle assessment, greenhouse gas emissions, carbon footprint, and sustainability, which constitute the central pillars of research in livestock-related environmental studies. In addition, frequently appearing terms such as environmental impacts, production systems, energy, and management indicate the field's strong application-oriented nature.

The presence of keywords related to specific production contexts, including milk production, livestock systems, and methane emissions, further emphasizes the sector-specific focus of the literature. At the same time, emerging terms related to mitigation, efficiency, and environmental performance indicate a growing emphasis on developing strategies to reduce emissions and improve sustainability outcomes in livestock production systems.

Taken together, these findings indicate that research on carbon footprint in livestock production is structured around a well-established core of environmental assessment methodologies, particularly life cycle assessment, while simultaneously expanding toward more applied, solution-oriented, and sustainability-driven approaches. The increasing diversity of keywords reflects a dynamic and evolving research landscape that responds to the need for more efficient, data-driven, and environmentally sustainable livestock production practices.

IV. CONCLUSION

This bibliometric analysis provides a comprehensive overview of the scientific literature on the carbon footprint of livestock production from 1980 to 2025. By integrating performance indicators and science mapping techniques, the study outlines the field's developmental trajectory, intellectual structure, and emerging research directions. The results reveal a consistent and accelerating increase in scientific output, particularly after the early 2010s, reflecting the growing global concern over climate change and the environmental impacts of livestock systems. The observed growth patterns indicate that the field remains in an active expansion phase, with significant potential for further thematic diversification and methodological advancement.

Geographic and collaboration analyses highlight a globally distributed research landscape, dominated by China, the United States, and several European countries, supported by increasingly strong international collaboration networks. These patterns underscore the importance of cross-border scientific cooperation in addressing complex, globally relevant environmental challenges associated with livestock production. Science mapping results demonstrate a well-defined intellectual structure centered around key concepts such as life cycle assessment, greenhouse gas emissions, and carbon footprint, alongside a wide range of application-oriented themes including production systems, environmental impacts, and sustainability strategies.

Thematic analyses further indicate a transition toward more integrative and solution-oriented research approaches. The growing emphasis on sustainability, emission mitigation, and efficiency improvements reflects the increasing need for environmentally responsible livestock production systems. Overall, the findings suggest that research in this field continues to evolve, offering substantial opportunities to develop innovative, data-driven, and policy-relevant solutions to support sustainable livestock management in the face of global environmental challenges.

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