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Artículo de revisión

Organic coffee production: mapping trends through bibliometric analysis

Producción de café orgánico: mapeando tendencias a través del análisis bibliométrico

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ABSTRACT

Organic coffee (OC) cultivation, known for its environmental advantages and potential economic value, is this article's focal point; because of the limited literature available, the objective is to pinpoint research trends in OC production to advance the sector's socioeconomic development. A bibliometric analysis was conducted by searching Scopus and Web of Science, while the Tree of Science (ToS) algorithm was applied to reveal the field's intellectual structure and current research trends, identifying a total of 360 scientific documents, reflecting a growing interest in various aspects of organic coffee; This article provides significant insights into the evolution of scientific production, the countries involved, prominent journals, authors, and their collaborative networks. Three key trends emerged: 1) Fair trade and gender equality, 2) Certifications and sustainability, and 3) Sustainable agroecological strategies. In conclusion, this study underscores the need for further research into various facets of organic coffee production, especially in countries where poverty alleviation and value creation are paramount.

Keywords: Coffee; organic production; sustainability; certification.

RESUMEN

La caficultura orgánica, con sus beneficios ambientales y su significativo potencial económico, constituye el núcleo central de este artículo. Se emprende un esfuerzo meticuloso para paliar la notoria escasez de literatura académica, identificando tendencias investigativas en la producción de café orgánico (OC), con el objetivo de catalizar el desarrollo socioeconómico en el sector. A través de un riguroso análisis bibliométrico de 360 documentos científicos meticulosamente recopilados de bases de datos prestigiosas como Scopus y Web of Science, se ha detectado un crecimiento sostenido en la investigación de diversos fenómenos intrínsecamente relacionados con el café orgánico. El estudio revela datos críticos sobre la producción científica, los países involucrados, las revistas académicas de renombre, los autores preeminentes y las redes de colaboración interinstitucionales. Además, se destacan tres tendencias clave en la investigación: 1) Comercio justo y equidad de género, 2) Certificaciones y sostenibilidad ambiental, 3) Estrategias agroecológicas sostenibles. En resumen, este estudio subraya vehementemente la importancia crucial de profundizar la investigación académica para afrontar con eficacia los desafíos multifacéticos que enfrentan los países productores de café orgánico y para superar la pobreza en estas regiones vulnerables.

Palabras clave: café; producción orgánica; sostenibilidad; certificación.
JEL: M110; Q57; A13

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INTRODUCTION

Belonging to the botanical family Rubiaceae, genus Coffea, species arabica, coffee possesses organoleptic properties; its pleasant and stimulating characteristics fulfill physiological, social, and cultural needs, leading to its constant and growing demand worldwide. As reported in the International Coffee Organization's (ICO) December Market Report 2023, global coffee consumption will witness a 2.2 % surge, reaching an impressive 177.0 million bags by 2024; in alignment with this burgeoning demand, coffee production is ready, thus favorably positioning coffee growers to meet the volume requisites of consumers.

Organic farming emphasizes environmentally friendly practices and principles to minimize environmental harm and frequently garners support from reputable organic certifications (Rich et al., 2018). Nonetheless, there exists a divergence of opinions among stakeholders due to the economic and financial risks associated with transitioning to agroecological methods (Bosa & Rover, 2021), making it essential to carefully assess the costs, expenditures, and financial viability of shifting from conventional to organic production (Carpio et al., 2023; Ibanez & Blackman, 2016), all while preserving product quality, value, and benefits for producers (Fernandes et al., 2014; Malta et al., 2008; Rojas Ruiz et al., 2021).

Several aspects of OC production are explorable, including the transition from conventional to organic systems in smallholder farms (Morris et al., 2013), monetary and non-monetary incentives through carbon-backed programs (Rahn et al., 2013), utilization of natural fertilizers (Grossman, 2003), and other organic materials that replace synthetic inorganic fertilizers. Some strategies include shade management and the introduction of earthworms, as mentioned by Resende et al. (2021) based on research by the National Federation of Coffee Growers of Colombia (Sadeghian, 2010), as well as the use of beneficial insects and repellent plants; shade crops are also promoted by planting taller trees around coffee plants, which protects biodiversity and soil health (Guimarães et al., 2014).

Research on OC production extends beyond technical aspects, also encompassing social dimensions which often involve engaging local communities, focusing on healthcare services, strengthening the education of producer families through fair employment (Sharma et al., 2020), enhancing the quality of life for producers (Häger et al., 2021), and supporting community projects (Valkila, 2009); this can include training local farmers in sustainable organic practices that consider the social disruptions that often occur (Jimenez-Soto, 2021) and have a significant impact on the market when making consumption decisions, as it highlights that the product belongs to a specific market niche available for differentiated products with ethical and environmentally crafted messages, as explained by Loureiro & Lotade (2005).

In summary, enough evidence suggests that research in OC production is highly relevant but remains scarce in understanding the field's nature and pertinent research trends. Methodologically, researchers conducted a literature search in Scopus and WoS to perform a bibliometric analysis using the Tree of Science (ToS) algorithm; this contribution's novelty lies in the diversity of quantitative and qualitative bibliometric results, combining three sources simultaneously.

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METHODOLOGY

The study done through scientometric analysis followed the parameters established in Table 1; given the importance of Latin American influence on coffee research, the Spanish keyword "café orgánico" was also used, and recognizing the field's multidisciplinary nature filters for specific areas were not applied; in addition, researchers included books, chapters, and conferences, recognizing the essential literature on coffee in these documents.

Table 1. Search Parameters and Results for OC Research in WoS and Scopus Databases

Parameters	Web of Science	Scopus
Range	2000 - 2023	
Date	January 1 del 2024	
Document types	Articles, books, chapters, and conferences	
Words	Title-Abstract-Keywords: (“organic coffee” OR “organic* production coffe*” OR “café orgánico”)	
Results	205	274
Total (Wos+Scopus)	360	

Source: Own elaboration.

Researchers utilized Scopus and WoS, leveraging their global reputation along the Tree of Science (ToS) algorithm for a comprehensive analysis (Grisales et al., 2023) and integrated data from both databases to identify critical OC research, standardizing references through text mining and web scraping, obtaining DOIs, and consulting CrossRef for essential information despite the limited details in WoS references.
Scopus references, though diverse, were parsed through text mining for authors, dates, titles, and journals, resulting in 360 unique articles.

Scientometric analysis, crucial for insights into annual production, international collaborations, journal themes, and researcher cooperation, was conducted in two sections; the first focused on scientific production, countries, journals, and cooperation, employing a collaboration network approach Hurtado-Marín et al. (2021), using reference authors, yielding a more interconnected structure and better insight into researchers' networking processes (Robledo, Eider, et al., 2022); this overview provides a comprehensive view of OC research dynamics for interested researchers.

The second section discusses theoretical contributions and OC trends using the ToS algorithm (Robledo, Zuluaga, et al., 2022; Valencia-Hernandez et al., 2020; Zuluaga et al., 2022); the algorithm positions articles at the root, trunk, and branches, constructing a narrative from foundational studies to current trends.
ToS was applied widely in management (Duque et al., 2024; Londoño & Cardona, 2024; Robledo et al., 2023)), health (Arbelaez et al., 2023), operations strategy (Vivares et al., 2022), and ecology (Ariza-Colpas et al., 2023; Botero et al., 2023), for a detailed explanation of ToS adoption and diffusion, refer to Eggers et al. (2022).

RESULTS

Scientometric Analysis

The analysis of annual scientific production helps to understand a particular subject's growth and peaks over time; Figure 1 illustrates the academic output of OC over the last 23 years using reference authors for a more

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interconnected structure and a better understanding of researchers' networking processes; overall, there was a growth of 17.69% during this period, indicating increased academic interest in the last three years.

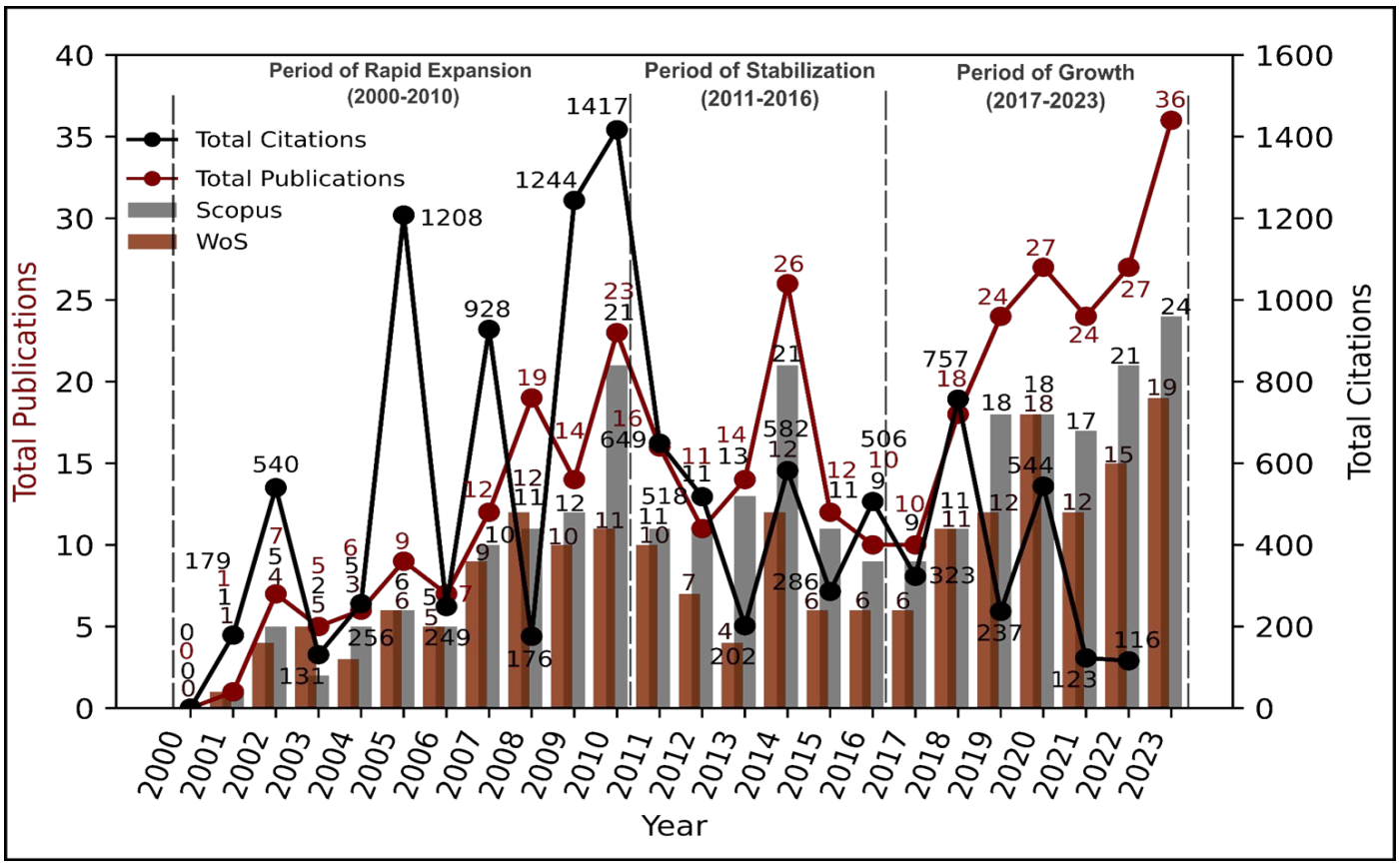

Figure 1. Trends in Coffee Research Publications and Citations: A Comparative Analysis of expansion, stabilization, and growth.
Source: Own elaboration based on data from the WoS and Scopus.

Country Analysis

Table 2 presents the top ten countries in academic OC research, focusing on Latin American nations like Brazil, Mexico, Peru, and Colombia due to their coffee export dependence; Brazil leads in academic production (28.88 %), while the USA leads in impact (37.46 %), despite not being a coffee producer, which may indicate publication quality and national interest in coffee consumption; for example, Brazil has 18 Q1 publications (Scimago ranking), compared to the USA with 33.

Table 2. International Coffee Production and Research Impact by Country

Country	Production		Citation		Q1	Q2	Q3	Q4
Brazil	108	28.88 %	1 163	14.81 %	18	25	29	9
USA	60	16.04 %	2 941	37.46 %	33	7	6	2
Mexico	38	10.16 %	665	8.47 %	14	4	2	4

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Indonesia	18	4.81 %	77	0.98 %	0	2	2	0
Colombia	13	3.48 %	178	2.27 %	2	2	2	2
Costa Rica	11	2.94 %	448	5.71 %	7	1	1	1
Spain	11	2.94 %	73	0.93 %	3	0	3	0
United Kingdom	10	2.67 %	293	3.73 %	4	4	0	1
Peru	9	2.41 %	52	0.66 %	2	1	0	2
Netherlands	8	2.14 %	264	3.36 %	2	5	1	0

Source: Own elaboration based on data from the WoS and Scopus.

Scientific collaboration networks, determined by co-author affiliations in articles, illustrate countries' contributions (Figure 2).

OC literature identifies seven country groups; the first, led by the USA, Germany, and Colombia, is characterized by collaborative work on Arabica coffee-producing regions in Latin America (Harvey et al., 2021); the second involves Brazil, Spain, and Mexico, with recent research on coffee berry borer control (Carvalho et al., 2023); the third, led by the United Kingdom, Costa Rica, and Canada, focuses on certified coffee farms' environmental behavior through econometric analysis.

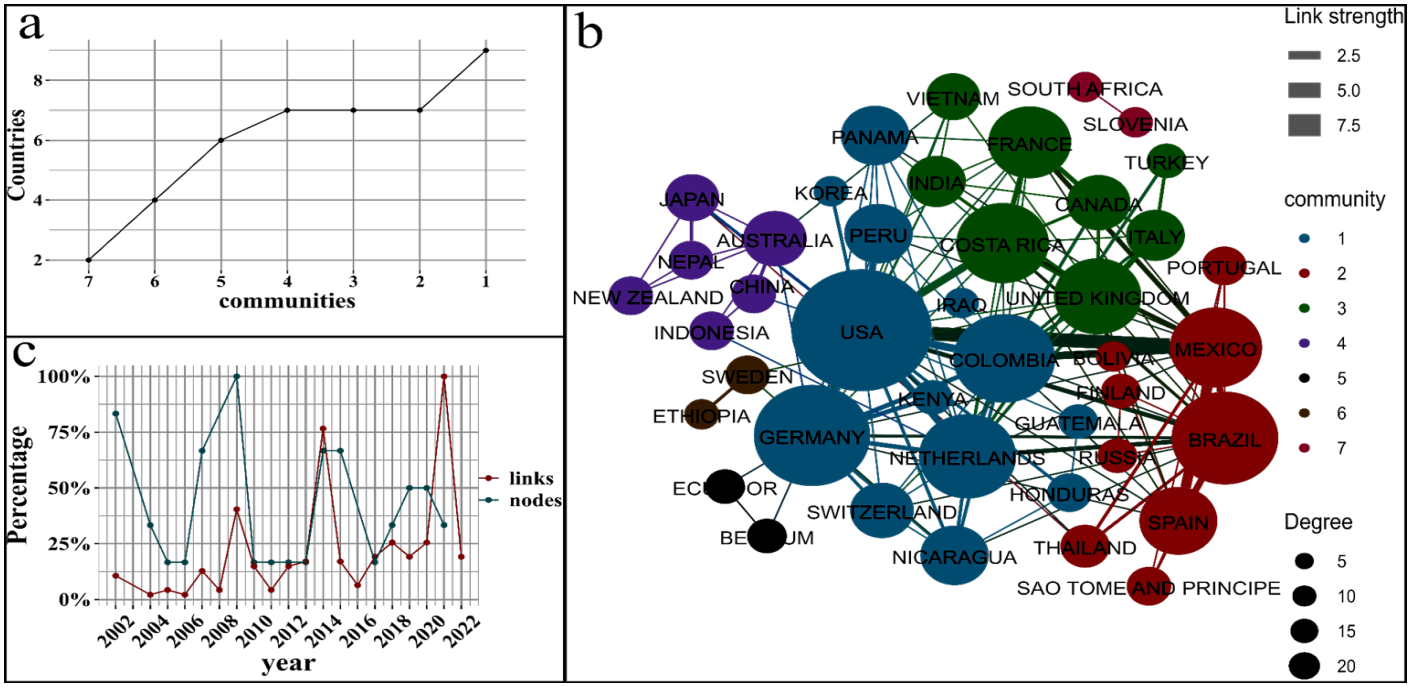

Figure 2. Global Collaboration Network: Country Interactions and Community Dynamics in Coffee Research. 2a. Total Number of Communities by Size. 2b. Nodes and Links Over Time. 2c. Scientific Collaboration Network of Countries.

Source: Own elaboration based on data from the WoS and Scopus.

Journal Analysis

Clío América / ISSN Impreso: 1909-941X / ISSN Web: 2389-7848 / Vol. 18 No. 35 enero – junio de 2024
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Table 3 outlines the top ten journals exhibiting the highest production of OC articles, indicating their keen interest in this subject; for instance, Coffee Science has published 25 articles and holds a position in Scimago's Q3 quartile.

The journal recently addressed OC production in Mexico, highlighting a global decline in its status (Zulith Flores-Anaya et al., 2022); notably, five of the ten journals are in the highest quartile (Q1); Ecological Economics, with the highest H-index (236), delved into an intriguing phenomenon among OC producers — their inclination towards higher quality without certifications, termed "beyond organic" (Starobin, 2021) Importantly, Table 3 shows balanced production between WoS and Scopus across these journals.

Table 3. Journal Metrics in Coffee Research: Impact Factor, Indexing, and Quartile Rankings

Journal	**Wos**	**Scopus**	**Impact Factor**	**H Index**	**Quantile**
Coffee Science	0	25	0.21	18	Q3
Ciencia E Agrotecnología	7	4	0.34	35	Q2
IOP Conference Series: Earth and Environmental Science	0	11	0.2	41	-
Agroecology And Sustainable Food Systems	6	6	0.63	51	Q1
Agroforestry Systems	4	4	0.66	87	Q1
Food Research International	5	5	1.36	195	Q1
World Development	5	4	2.5	206	Q1
Ciencia Rural	2	2	0.24	43	Q3
Ecological Economics	4	3	1.9	236	Q1
Neotropical Entomology	2	0	0.55	54	Q2

Source: Own elaboration based on WoS, Scopus, and Scimago Journal Rank data.

Figure 3 displays a citation network among journals, revealing three distinct groups: agricultural topics (Fernandes et al., 2011; Vaidya et al., 2023), Ecological aspects of OC (Etafa et al., 2023; Häger, 2012), and the chemical processes of OC (Bedoya et al., 2017; Gallardo-Ignacio et al., 2023).

These well-defined themes showcase different orientations in OC research, and the figure shows a significant increase in links after 2009, indicating a well-established and growing area of knowledge.

Clío América / ISSN Impreso: 1909-941X / ISSN Web: 2389-7848 / Vol. 18 No. 35 enero – junio de 2024
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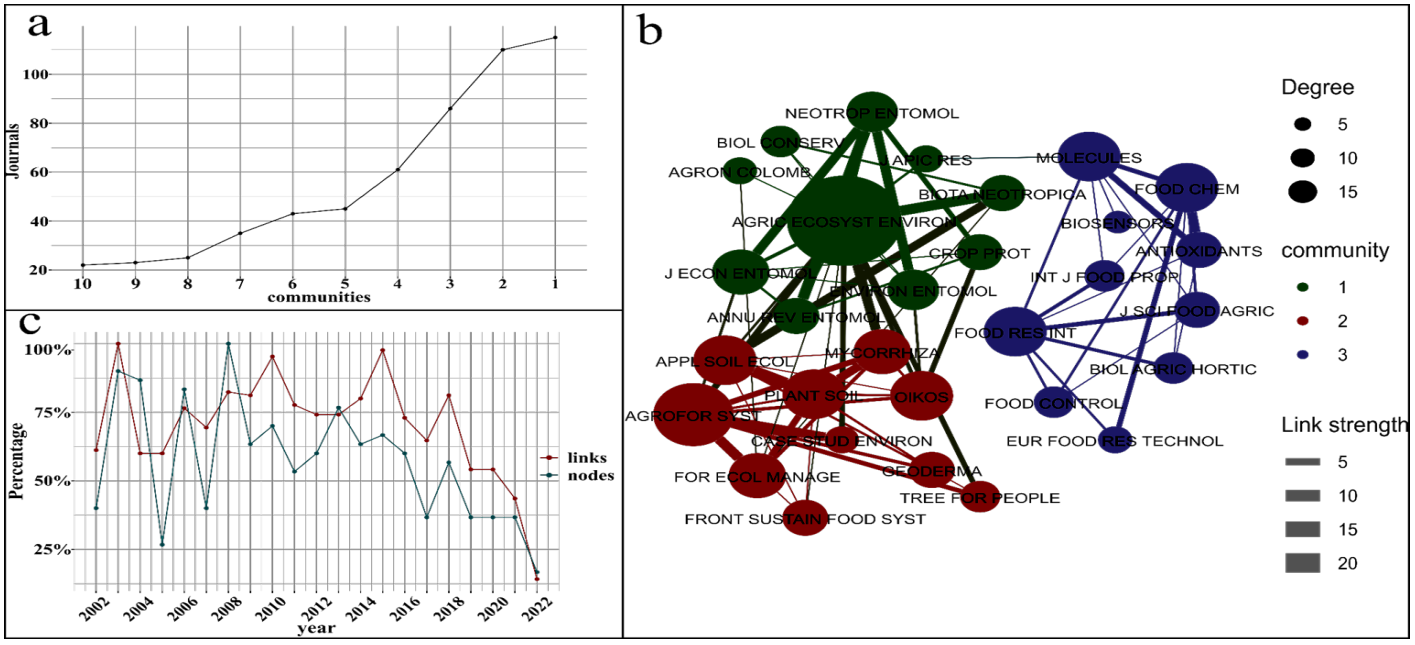

Figure 3. The Dynamics of Scholarly Collaboration: Author Networks and Community Engagement Over Time in Coffee Research. 3a. Total Number of Communities by Size. 3b. Nodes and Connections Over Time. 3c. Scientific Collaboration Network among Journals.
Source: Own elaboration based on data from the WoS and Scopus.

Author Collaboration Network

Table 4 presents the top ten most prolific OC authors; Professor Maurício Sérgio Zacarias leads with the most articles, notably recognized for contributions to OC and biological pest management (Scalon et al., 2011); Raul Guedes holds the highest h-index, acclaimed for his work on solutions for coffee berry borer management (Carvalho et al., 2023).

The table highlights significant contributions from countries such as Brazil and the United States in OC management.

Table 4. Production By Author

No	Researcher	Total Articles*	Scopus H-Index	Affiliation
1	Zacarias M	7	8	Empresa de Pesquisa Agropecuária de Minas Gerais, Lavras, Minas Gerais, Brazil
2	Maffia L	6	23	Universidade Federal De Vicosa, Vicosa, Brazil
3	Mizubuti E	6	32	Universidade Federal De Vicosa, Vicosa, Brazil
4	Mutersbaugh T	6	13	University Of Kentucky, Lexington, United States
5	Perfecto I	6	55	University Of Michigan, Ann Arbor, Ann Arbor, United States
6	Ricci M	6	9	Embrapa Agrobiologia, Seropedica, Brazil
7	Vandermeer J	6	53	University Of Michigan, Ann Arbor, Ann Arbor, United States
8	Venzon M	6	23	Empresa De Pesquisa Agropecuária De Minas Gerais, Belo Horizonte, Brazil
9	Azevedo L	5	26	Universidade Federal De Alfenas, Alfenas, Brazil

Clío América / ISSN Impreso: 1909-941X / ISSN Web: 2389-7848 / Vol. 18 No. 35 enero – junio de 2024
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10	Guedes R	5	57	Universidade Federal De Vicosa, Vicosa, Brazil

Source: Own elaboration based on data from the WoS and Scopus.

Figure 4 illustrates the scientific collaboration network among the top authors (Table 4), consisting of seven components; the largest component highlights Professor Ivette Perfecto and John Vandermeer, renowned for their joint research on biological pest control in OC production (Vandermeer et al., 2010; Vandermeer & Perfecto, 2006); the second component features Professors Madelaine Venzon and Raul Narciso C. Guedes, focusing on pest control in OC, specifically the red spider mite.
The network appears disjointed, showcasing diverse themes among the most productive authors, and the figure reveals a growing ratio of links to nodes (authors) over time, especially post-2015, indicating heightened collaborations and a strengthened scientific community.

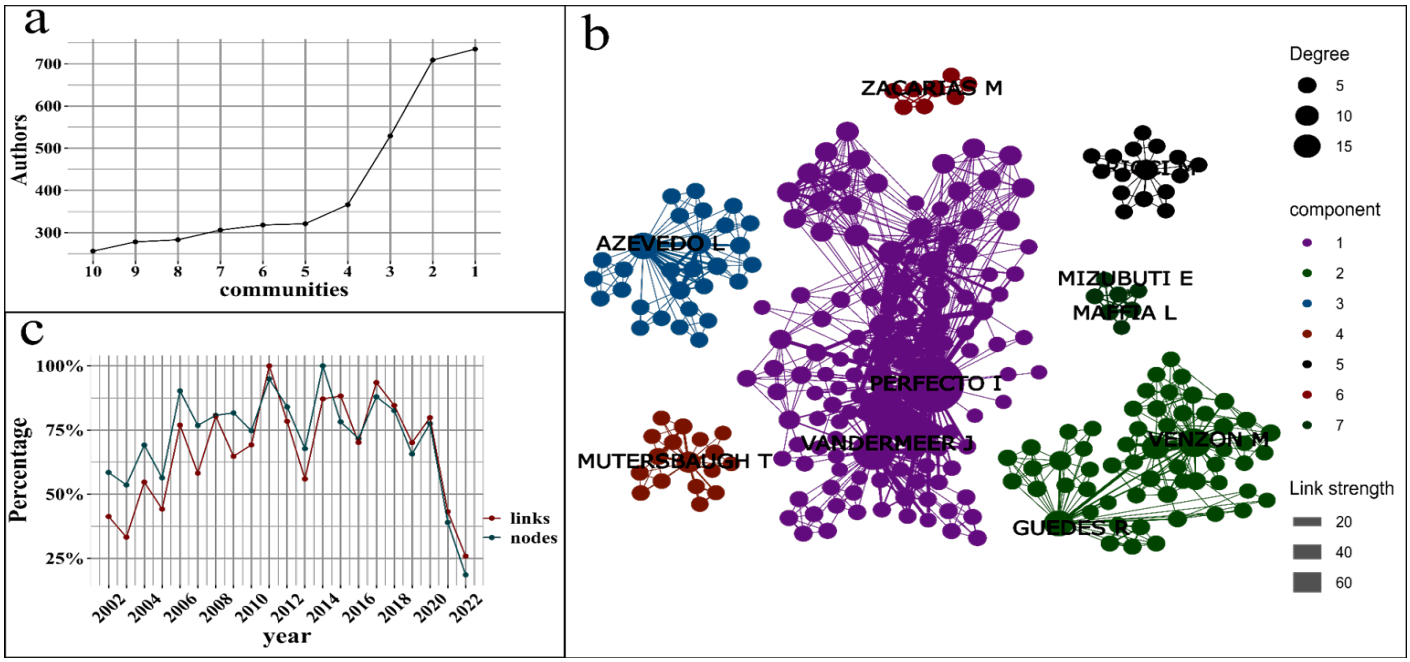

Figure 4. The Dynamics of Scholarly Collaboration: Author Networks and Community Engagement Over Time in Coffee Research.4a. Total Number of Communities by Size. 4b. Nodes and Connections Over Time. 4c. Scientific Collaboration Network by Authors.
Source: Own elaboration based on data from the WoS and Scopus.

Tree of Science

Roots

In the analogy of a tree, the ToS algorithm aids in identifying seminal articles that significantly contributed to the field's early development; among these, the following works are particularly significant:

The article by Perfecto et al. (1996) analyzes the ecological and socioeconomic benefits of shade-grown coffee, an agroforestry system hosting diverse plant and animal species; similarly, Perfecto et al. (1996) examined the connection between coffee production and biodiversity conservation in Mexico, focusing on crops grown under native tree shade; they found that the traditional system has the highest diversity, followed by rustic and modern systems.
Both studies advocate strategies for preserving shade-grown coffee, including differentiated markets, ecological certification, environmental education, and participatory research; these approaches emphasize integrating ecological, social, and economic aspects to enhance carbon monoxide OC sustainability and highlight the historical significance of shade-grown coffee in the OC spectrum.

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Bray et al. (2002) explored OC production organizations in Chiapas and Oaxaca, revealing positive impacts on community organization, income diversification, health, education, and indigenous culture preservation; challenges include external certifications, limited government support, and the exclusion of some producers. Addressing these requires an inclusive, participatory approach involving stakeholders.

Collectively, these three references have played pivotal roles in OC research, highlighting a wide range of phenomena demanding attention; these encompass technical production aspects relevant to agricultural sciences, as well as social, economic, and environmental dimensions of interest to various scientific communities such as management, psychology, economics, and engineering.

Trunk

The ToS algorithm identifies works supporting the sustainable agriculture field, covering biological, commercial, economic, social, biodiversity, and environmental aspects.

Mutersbaugh (2002)analyzes the impact of OC certification on economic management and governance among producers in Oaxaca, Mexico; certification alters the logic and practice among producers, necessitating a reevaluation of assistance for certifying producers in promoting AS.
Similarly, Philpott et al. (2007) suggest that certification ensures economic and ecological benefits, with certified fair trade farms protecting biodiversity and improving coffee farmers' situation.
Conversely, Muleta et al. (2007) highlight how shade-grown coffee optimally conserves shade tree biodiversity and enhances carbuncular mycorrhizal fungi properties; they propose using shade legumes to improve soil and coffee fertility.

Valkila (2009) examines the impact of OC production on the well-being of small farmers and the environment, revealing that fair trade production increases farmers' incomes compared to conventional production, which necessitates higher government intervention through public policies to improve living conditions; similarly, Bolwig et al. (2009) evaluate certified organic agriculture (OA) schemes in income and incentives for OC cultivation.
Lyon (2009) identifies tensions between producers, the market, and OC as a liberating practice for producers and the environment, which acts as a force reshaping the political economy and reconfiguring the culture and identity of coffee growers.

Branch 1: Fair Trade and Gender Equity: Pathways to Empowerment in Global Coffee Markets

The Tree of Science (ToS) algorithm has sparked a growing demand for research guiding the development of fair markets through policies.
Tucker & Pérez (2023) conducted a study on Organic Coffee Marcala (COMSA) in Honduras, a Fairtrade-certified organization; their findings revealed that COMSA utilized fair trade income to establish a multilingual school incorporating biodynamic principles, indigenous knowledge, and experimentation.

In Africa, Addisie & Tebarek (2023) explored opportunities and challenges for enhancing small coffee producers in Ethiopia's Sidama region; despite some producers capitalizing on opportunities driven by increasing demand for OC, limitations such as inadequate investment capital, farmers' lower education levels, and poor infrastructure hindered their ability to seize these opportunities.

Furthermore, Flachs & Panuganti (2020) investigated variations in organic agriculture in southern India, exploring how organic farming creates opportunities within supply chains; the study highlighted barriers for farmers in accessing organic markets and obtaining certifications, hindering their economic and social gains.

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Similarly, Estevez et al. (2018) focused on coffee production in Bolivia, revealing economic benefits for producers and intermediaries involved in fair trade and organic markets despite challenges like increased production costs and stagnant prices.

Researchers have also delved into the role of women in fostering equitable markets; Lyon et al. (2017) focused on the increased participation of women in fair trade organic products in Oaxaca, Mexico, while Bilfield et al. (2020) examined perspectives within the Guatemalan coffee supply chain regarding transformative gender change.
These studies indicate that women while making progress in asserting their agency and managing their coffee income, face challenges such as the disproportionate burden of domestic work, the need for technical support, and the necessity of a more inclusive social and political environment hindering their participation and leadership in coffee organizations.

Branch 2: Certification and Sustainability: Pathways for Rural Coffee Enterprises in Latin America

Risueño et al. (2023) shed light on the challenges coffee producers face in the Cauca department in Colombia as they pursue certifications, highlighting social, economic, and cultural constraints within family production units in coffee-growing areas stemming from stringent quality standards imposed by organic certification bodies; the authors argue for shade-grown coffee as a sustainable and profitable choice, offering economic benefits while preserving the environment and coffee quality.

This strategy has gained popularity in Latin American regions, where obtaining organic certification is seen as a sustainability approach, granting access to larger markets in countries like the United States, European nations, and Asian markets.

Coffee farms are transforming into robust rural enterprises, as Häger et al. (2021) emphasize, turning challenges into opportunities; small coffee growers increasingly adopt environmental sustainability practices, leading to the growth of agro-ecotourism experiences.

This intertwining of tourism expectations with coffee production is evident; Winter et al. (2020) observed improved performance in certified environmental, social, and governance systems in Brazil using the Sustainability Monitoring and Assessment RouTine (SMART)-Farm tool.

However, in Ethiopia, economic gains were constrained by financial limitations and profit distribution within coffee cooperatives; the rise of organic agriculture brings forth voluntary quality certifications, which, through stringency, may pose challenges when pursued independently, as Bray (2019) states, institutional intervention appears more promising in such cases.

In Central American coffee-producing nations, as emphasized by Bro et al. (2019) in Nicaraguan communities, joining cooperatives plays a crucial role in promoting sustainable production; cooperatives also serve as a legal entity for representation, facilitating collective efforts to conserve natural resources, safeguard water sources, and enhance collective adaptive capacity in response to climate change.

Branch 3: Sustainable Agroecological Strategies in Organic Coffee Production: Pollinators, Soil Health, and Biodiversity Conservation.

This research area delves into ecosystem management strategies concerning carbon monoxide and OC.

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Vaidya et al. (2023) discovered that various habitats, including traditional coffee farms and forests, significantly impact the pollen diets of stingless bee colonies.
Fitch et al. (2022) indicate that coffee competes with neighboring plants for pollination, affecting product quality; they propose managing coffee agroecosystems to preserve plant density and diversity without yield loss, promoting biodiversity conservation in agriculture.
Ants, acting as ecosystem indicators, were examined by Aponte-Rolón & Perfecto (2023), who studied the influence of leaf litter on ant communities in shaded coffee agroecosystems, revealing complexity influenced by nearby forest trees.
All these studies emphasize environmental factor identification (bees, ants, and soil) for effective coffee crop management.

The role of small farmers in fostering sustainable ecosystems for carbon monoxide OC cultivation is crucial; López-Carmona et al. (2024) highlight the impact of soil properties on OC quality, noting that farmers consider altitudes above 1,400 meters above sea level ideal for these crops.
Environmental factors, such as climate change, influence OC quality; recent research reveals that climate change elevates pest and pathogen pressure on coffee plantations and soil microbial communities, posing new challenges for coffee crop management and emphasizing the significance of climate change adaptation.
Additionally, researchers recognized emerging small specialty coffee farms as crucial agrobiodiversity hubs; Archibald et al. (2022) suggest studying and managing herbaceous community functional diversity in these systems while considering farmers' perspectives.

DISCUSSION

The results show that the number of publications on OC has increased significantly in recent years; between 2000 and 2008, the production in both databases was relatively even, but post-2009, Scopus began to dominate. However, when considering the total unique articles from both databases (red line), the databases present different articles, confirming the need for scientometric studies that combine information from both databases simultaneously; researchers divided the scientific production into three periods for further analysis.

Period of Rapid Expansion (2000-2010)

Between 2000 and 2010, the percentage of scientific production was 41.68 %, with five significant peaks measured by the impact or citations received during this period (purple line); the first peak was generated by the discovery of the influence of economic management and governance in the union of peasant producers (Mutersbaugh, 2002); the second peak resulted from contributions to understanding consumer preferences related to ethically and environmentally responsible labeling programs (Loureiro & Lotade, 2005).
Overall, this period is characterized by high academic productivity, with studies that made a significant impact on OC research.

Period of Stabilization (2011-2016)

Unlike the previous period, the stabilization period is marked by stagnation in academic production (-8.97 %); in terms of impact, the articles show a homogeneous pattern of received citations, without peaks as high as in the previous period.

Period of Growth (2017-2023)

This period shows a 23.80% growth in OC research interest, with a peak in citations in 2018 due to a study on agroecology gaining global acceptance (Mier y Terán Giménez Cacho et al., 2018); this underscores the need for ongoing OC research and its revived interest in the academic community.

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In countries such as Colombia, Brazil, and Mexico, several emerging research trends include agroecology, agroforestry, sustainability, coffee quality, and technological innovation; these themes reflect a commitment to improving coffee cultivation's productivity and profitability while minimizing environmental and social impact.
However, there is a lack of empirical studies, rigorous program evaluations, and policy assessments promoting OC; additionally, there's insufficient attention to cultural and gender-related aspects in coffee production and marketing.
It is important to note that country classifications include non-coffee-producing nations, while many coffee-producing countries have limited scientific output, highlighting the need to encourage research in these countries.

CONCLUSION

This study concludes that scientific contributions to OC have increased by 23.80% in the last seven years, highlighting its importance for developing countries; notably, Latin American nations such as Brazil, Mexico, Colombia, Costa Rica, and Peru feature prominently within countries with high scientific output, reflecting the economic dependence of developing nations on agriculture and efforts to improve OC-related products.

Seven of the top ten journals with the most publications are in the highest quartiles (Q1 and Q2), and six of the top ten most productive authors are in Brazil.

In current OC research trends, three key themes have emerged; the first focuses on establishing fair markets, highlighting the vulnerability of small OC producers in negotiations with large marketers, and advocating for public policy regulation; the second trend centers on sustainability in OC production methods, acknowledging the need for specialized training to maintain product quality, especially among small coffee growers; the third trend involves identifying environmental challenges and requirements related to the impact of OC cultivation on soil, insects, and surrounding forests.

Declaration on conflicts of interest

The authors declare that they have no conflicts of interest.

Authors' Contribution

The authors declare they were solely responsible for conducting research, design, and structuring in this article.

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