Bibliometry of the environmental valuation of ecosystem services in shaded coffee cultivation

Bibliometria da valoração ambiental dos serviços ecossistémicos na cultura do café sombreado

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Abstract: This study presents the first bibliometric analysis of the international scientific literature on the environmental valuation of ecosystem services in shaded coffee cultivation systems, covering the period from 1995 to 2023. Based on data retrieved from the Web of Science and analyzed using VOSviewer software, a total of 132 documents were examined. The results indicate that this is a recent and fragmented research field, with a significant increase in publications after 2019. The performance analysis revealed a concentration of studies in the fields of Environmental Sciences, Environmental Studies, and Agronomy, with the United States, Brazil, and several European countries as leading contributors. The network analyses (keyword co-occurrence, bibliographic coupling, and co-citation) identified three main research fronts: ecosystem service provision, agroforestry management, and sustainability certification mechanisms, while also highlighting research gaps in economic valuation, governance frameworks, and farmer decision-making processes. The study concludes by emphasizing the need for greater interdisciplinary integration to advance the field and guide future research.

Keywords: Bibliometric Analysis; Shaded Coffee; Ecosystem Services; Sustainability; Environmental Valuation.

Resumo: Este estudo apresenta a primeira análise bibliométrica da literatura científica internacional sobre a valoração ambiental dos serviços ecossistêmicos em sistemas de café sombreado, abrangendo o período de 1995 a 2023. A partir de uma busca na base Web of Science e utilizando o software VOSviewer, foram selecionados 132 documentos para análise. Os resultados evidenciam que o campo de estudo ainda é recente e fragmentado, com aumento expressivo de publicações a partir de 2019. A análise de desempenho apontou maior concentração de estudos nas áreas de Ciências Ambientais, Estudos Ambientais e Agronomia, com destaque para os Estados Unidos, Brasil e países europeus. As análises de rede (coocorrência de palavras-chave, acoplamento bibliográfico e co-citação) revelaram três principais frentes de pesquisa: provisão de serviços ecossistêmicos, gestão agroflorestal e mecanismos de certificação de sustentabilidade, além de indicar lacunas em temas como valoração econômica, governança e decisão dos produtores. O estudo conclui apontando a necessidade de maior integração interdisciplinar para fortalecer o campo e orientar futuras pesquisas.

Palavras-chave: Análise Bibliométrica; Café Sombreado; Serviços Ecossistêmicos; Sustentabilidade; Valoração Ambiental.

Introduction

Studies concerning sustainable land use models demonstrate a notable upswing in recent times (UNEP, 2019) as a way to tackle the global competition scenario between agricultural activities and biodiversity conservation in forest areas (Tscharntke *et al.*,

2012). In this context, works such as agricultural activities based on an agroforestry system—as in shaded coffee growing—have emerged as pivotal for building a sustainable agricultural model.

Some studies (Hernandez-Aguilera *et al.*, 2019; Cerda *et al.*, 2017; Koutouleas *et al.*, 2022) reveal that the shaded coffee cultivation is intricately connected to biodiversity conservation, since it offers regulation services such as pest and disease controls and mitigation of the negative climate change effects (Zaro *et al.*, 2023; Lara-Estrada *et al.*, 2023; Coltri *et al.*, 2019). Cerda *et al.* (2020) found coffee agroforestry system to be a promising strategy for disease control and ecosystem service augmentation.

Assessing the ecosystem service values of a crop system allows measuring the society's well-being gains. In recent years, the environmental valuation studies have increased aiming to assess the individuals' preferences towards economic services (Guijarro and Tsinaslanidis, 2020; Ortiz, 2018; Pascual *et al.*, 2012). This literature has not been extensively reviewed systematically in order to show the state of the art and identify the gaps, which can guide future researches, especially about shaded coffee cultivation.

In recent decades, bibliometric techniques have been increasingly applied in systematic literature reviews (Kalantari *et al.*, 2017). Bibliometrics is a research methodology based on statistical analysis of publications related to a specific scientific topic. It allows for the statistical description of publication characteristics, such as authorship, co-authorship, country of publication, and institutional affiliation (Li and Zhao, 2015). In this context, bibliometric analysis serves as a valuable tool for revealing research trends and identifying knowledge gaps. Aria and Cuccurullo (2017) highlight the relevance of this method for producing reliable scientific mapping in the face of a rapidly growing body of publications that often generate fragmented and sometimes conflicting knowledge.

Within the agricultural domain, and especially in the context of coffee cultivation, several bibliometric studies have gained prominence. Santana *et al.* (2021) conducted a bibliometric review aimed at identifying advances in coffee cultivation research over the past 20 years. In the field of environmental valuation, Santos *et al.* (2023) carried out a bibliometric survey to determine the main research approaches, the most frequently publishing authors, and the leading countries in terms of methodological contributions. Additionally, Velasco-Munhóz *et al.* (2022) analyzed the evolution of research on the economic valuation of ecosystem services over the last two decades.

Studies applying bibliometric analysis to the environmental valuation of ecosystem services in shaded coffee cultivation are currently unavailable. This research aims to address this gap by analyzing the most influential publications in the field published between 1995 and 2023. Furthermore, we seek to identify trends in the application of environmental valuation to shaded coffee cultivation systems, as well as to highlight key advances and remaining research gaps on this topic. To carry out this analysis, we used the VOSviewer software and collected scientific publications indexed in the Web of Science database.

The novelty of this study lies in mapping the main publications on the environmental valuation of ecosystem services in shaded coffee farming, identifying research trends, and highlighting knowledge gaps on this topic.

The article is structured into four sections. Section one presents a literature review on bibliometrics analysis of environmental valuation in agroforestry coffee farming. Section two describes the methodology adopted for the bibliometric analysis. In section three, the results are presented and discussed. Finally, section four addresses the main conclusions of the study.

1. Bibliometric analysis of environmental valuation in agroforestry coffee farming

The term "bibliometrics" was introduced in 1969 by Alan Pritchard, as an alternative to the term "statistical bibliography", which had been in use within scientific circles since 1922 (Pritchard, 1969). Pritchard questioned the clarity of the earlier term, arguing that it was often confused with either the field of statistics itself or bibliographies related to statistics. The use of bibliometrics involves evaluating both the research performance and the scientific paradigms that shape a particular field of study (Donthu *et al.*, 2021).

Bibliometrics is defined as a quantitative method that applies mathematical and statistical techniques to monitor the evolution of a specified scientific field, taking account patterns of authorship, publication and the use of research results (Costa *et al.*, 2012). This tool is frequently used for bibliographic mapping, authorship and co-authorship analysis, co-citation studies, and for identifying research trends and knowledge gaps.

In recent decades, this method has been increasingly employed across various scientific fields (Aria and Cuccurullo, 2017). Its growing use has been facilitated by the development of more sophisticated search tools, advanced software, and extensive databases (Donthu *et al.*, 2021). Currently, bibliometric analysis is widely applied for multiple purposes and has been adapted to address diverse research questions (Oliveira *et al.*, 2019).

The research question addressed in this study focuses on the bibliometric analysis of environmental valuation in agroforestry coffee cultivation systems. These systems have been recognized for their role in enhancing ecosystem conservation capacity (Hernandez-Aguilera *et al.*, 2019). Agroforestry represents a type of constructed ecosystem characterized by complex interactions between the biotic and abiotic components of both agricultural and forestry activities (Maltby *et al.*, 2012). Such systems deliver a wide range of ecosystem services—including provisioning, regulating, cultural, and supporting services—all of which contribute directly or indirectly to human well-being (Zhang *et al.*, 2023; UN, 2005).

The contribution of the agroforestry coffee farming for ecosystem conservation has been well documented. Atallah *et al.* (2018) described how shaded coffee cultivation contributes to biodiversity conservation and its connection to economic and social

development. Atallah (2018) argued that coffee plants contribute to pest control by lowering the temperature around the coffee cherries and by improving soil fertility.

The socioeconomic aspects of agroforestry coffee farming are closely linked to both subsistence and income generation for farming households (Cerda *et al.*, 2020). In addition to coffee, agroforestry systems can produce a range of marketable goods, such as fruits, timber, firewood, and other products and services that contribute to household livelihoods (Somarriba *et al.*, 2013). Furthermore, the agricultural management practices implemented by coffee growers can achieve certification, enabling their coffee to be classified as specialty coffee and granting them access to more specialized market segments.

2. Methodology

This section presents the bibliometric methods and analytical procedures employed in this study, detailing the steps followed, the analytical approach adopted, and the search terms used.

2.1. Bibliometric Method

In this study, we follow the bibliometric method proposed by Donthu *et al.* (2021), which involves both performance analysis and scientific mapping (or network analysis) of the publications. Performance analysis focuses on selecting key metrics to evaluate the impact of publications within the research field, whereas scientific mapping improves the visual interpretation of these contributions by structuring them based on authorship, citation counts, co-citation patterns, bibliographic coupling, and keyword co-occurrence.

2.2. Steps of the Method

The bibliometric analysis conducted in this study followed a structured and widely recognized methodological framework (Donthu *et al.*, 2021; Aria and Cuccurullo, 2017). The process was divided into seven distinct steps as described in Figure 1.

Step 1: Definition of the Study Topic

According to Donthu *et al.* (2021), this stage involves clearly defining the study topic and establishing the research question that guides the bibliometric investigation. Therefore, the present study focuses on conducting a bibliometric analysis of scientific literature addressing valuation of ecosystem services provided by shaded coffee cultivation systems. This research topic lies at the intersection of agroforestry, environmental economic valuation, and ecosystem services.

Step 2: Database Selection

The second step consists of selecting a reliable and comprehensive bibliographic database. In this sense, the Web of Science (WoS) database was selected as the primary source for this bibliometric analysis. WoS is a widely recognized and internationally credible bibliographic database, known for its rigorous data standardization and comprehensive coverage across scientific disciplines. These

characteristics ensure consistency, accuracy, and reliability in the retrieval and processing of bibliometric data.
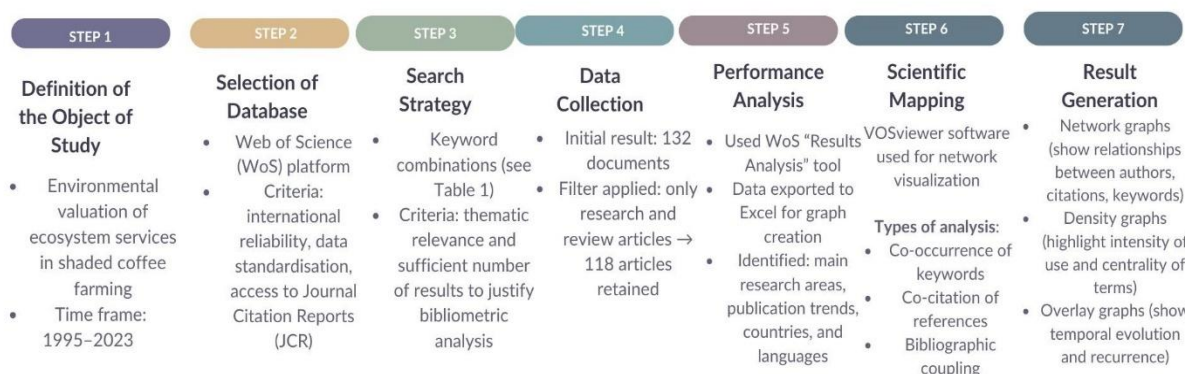
METHODOLOGICAL FLOWCHART

STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7
Definition of the Object of Study	**Selection of Database**	**Search Strategy**	**Data Collection**	**Performance Analysis**	**Scientific Mapping**	**Result Generation**
• Environmental valuation of ecosystem services in shaded coffee farming • Time frame: 1995–2023	• Web of Science (WoS) platform • Criteria: international reliability, data standardisation, access to Journal Citation Reports (JCR)	• Keyword combinations (see Table 1) • Criteria: thematic relevance and sufficient number of results to justify bibliometric analysis	• Initial result: 132 documents • Filter applied: only research and review articles → 118 articles retained	• Used WoS "Results Analysis" tool • Data exported to Excel for graph creation • Identified: main research areas, publication trends, countries, and languages	VOSviewer software used for network visualization **Types of analysis:** • Co-occurrence of keywords • Co-citation of references • Bibliographic coupling	• Network graphs (show relationships between authors, citations, keywords) • Density graphs (highlight intensity of use and centrality of terms) • Overlay graphs (show temporal evolution and recurrence)

Figure 1: Methodological Flowchart
Source: Authors (2025).

Furthermore, the platform provides access to impact factor metrics through the Journal Citation Reports (JCR), a widely recognized reference for evaluating the scientific relevance and influence of academic journals. The impact factor facilitates the systematic classification of journals according to their scholarly impact and their contribution to advancing knowledge within their respective fields (Albort-Morant *et al.*, 2017).

Step 3: Development of the Search Strategy

In this stage, a specific search strategy is developed to retrieve the most relevant publications related to the research topic. According to Aria and Cuccurullo (2017), the accuracy of the search strategy is crucial to minimizing false positives and ensuring the inclusion of key literature.

The search strategy for this bibliometric analysis was developed based on three main criteria, following the methodological guidelines of Donthu *et al.* (2021): (i) conceptual alignment with the defined research topic and publication in the field of study; (ii) ability to yield a sufficient volume of publications to warrant the use of bibliometric techniques; and (iii) defined time period.

The selected keywords were chosen to reflect the core concepts of the study, focusing on the environmental valuation of ecosystem services in shaded coffee cultivation systems. This ensured that the retrieved publications were directly relevant to the field of interest. Table I presents the selected keywords.

Table I: Selected Keywords

Search	Keywords
1	"Shaded Coffee" OR "Sustainable Coffee" AND Valuation
2	"Sustainable Coffee" OR "Shaded Coffee" AND Valuation
3	Valuation AND "Shaded Coffee" OR "Sustainable Coffee".
4	"Shaded Coffee" OR "Sustainable Coffee" AND "Ecosystem Service Valuation" and "Coffee Valuation"
5	"Environmental Economic Valuation" OR "Valuing Ecosystem Services" AND "Shaded Coffee" OR "Sustainable Coffee"

Source: Authors (2023).

Key terms central to the search strategy include "shaded coffee", "ecosystem services", "sustainable", and "economic valuation", each defined as follows.

The term "shaded coffee" is associated with the traditional polyculture system, conceptualized by Toledo and Moguel (2012) as the combination of the coffee plant with a diversity of tree, shrub, and herbaceous species, originating from natural and introduced vegetation.

The concept of "ecosystem services" encompasses the various benefits that humans obtain from natural ecosystems, typically categorized as provisioning, regulating, supporting, and cultural services, according to the Millennium Ecosystem Assessment (MEA, 2005). In this regard, agroforestry coffee farming delivers a range of ecosystem services. Provisioning services include drinking water, timber, genetic resources, and coffee production. Regulating services encompass climate regulation and water quality improvement. Supporting services involve soil formation, pollination, nutrient cycling, and habitat provision for biodiversity. Finally, cultural services include opportunities for rural tourism.

The term "sustainable" refers to the long-term capacity to maintain the ecological functions of an ecosystem. It implies the use of natural resources at stable and controlled levels that do not compromise environmental integrity for future generations (Collins, 2022). Agroforestry coffee farming is recognized as an agricultural practice that fosters economic development while achieving economic efficiency, social equity, and environmental sustainability (Onyas *et al*., 2018).

Finally, the term "economic valuation" refers to the process of estimating the importance or worth of ecosystem services provided by natural resources. This valuation is not restricted to monetary terms but may also include qualitative and quantitative approaches that reflect the preferences, perceptions, and priorities of different social groups (Ortiz, 2018). In the specific context of agroforestry coffee farming, economic valuation plays a crucial role in quantifying and demonstrating the multiple benefits that shaded coffee systems provide beyond coffee production.

The initial data screening revealed that the earliest publication on the investigated topic dates back to 1995, leading us to set the study period from 1995 to 2023.

Step 4: Data Collection

The fourth step refers to the systematic extraction of bibliographic data from the selected database. The records typically include information such as titles, abstracts, authors, affiliations, publication years, keywords, and citation counts. This raw data serves as the foundation for subsequent performance and mapping analyses (Donthu *et al.*, 2021).

Combining the selected search terms, 132 documents yielded from the Web of Science Core Collection. After applying a refinement filter to include only research articles and review papers, the final dataset comprised 118 publications, which formed the basis for the analyses presented in this study.

Step 5: Performance Analysis

Performance analysis focuses on evaluating scientific productivity and impact within the chosen research field. In this study, it aimed to provide a quantitative description of the publications retrieved from the Web of Science database. For this purpose, we applied descriptive statistical techniques, including absolute and relative frequency analyses, to examine the distribution of publications by research field, year of publication and country of origin. The data were organized in Excel spreadsheets, which were also used to generate descriptive tables.

Step 6: Scientific Mapping

The sixth step involves applying bibliometric mapping techniques to visualize the intellectual, social, and conceptual structures of the research field (Donthu *et al.*, 2021). In this study, a network analysis was performed using tools available in the VOSviewer software (Available at: http://www.vosviewer.com). The objective was to visualize bibliometric networks based on the proximity and strength of relationship between elements within the dataset (Eck and Waltman, 2014). This approach enables the construction of different types of relational networks, such as citation networks, bibliographic coupling, co-citation, and co-authorship networks, facilitating the identification of research clusters and thematic connections.

All keywords' co-occurrence parameters, the references' co-citation and the bibliographic coupling of documents were considered. The co-occurrence of a keyword involves the number of publications in which two keywords transpired simultaneously in the title, abstract or list of keywords (Rojas-Lamorena *et al.*, 2022; Zupic and Cater, 2015). The keywords' internal strength links to how often they are implemented, i. e., with heightened recurrence in usage, these terms' core potency are amplified within the cluster. The density that measures these keywords' internal strength or networks, plus their centrality, refers to the degree of interaction between the networks (Rojas-Lamorena *et al.*, 2022).

The references' co-citation recognizes that if two publications are repeatedly cited together it means that they present thematic similarity (Hjørland, 2013). This mapping technique usage facilitates the pinpointing of the most influential publications on a selected topic, providing access to seminal works (Donthu *et al.*, 2021).

The bibliographic coupling technique is based on the assumption that the more two documents share common references, the greater their degree of similarity and thematic homogeneity (Donthu *et al.*, 2021). As stated by Zupic and Cater (2015, p.434), "*the more the bibliographies of two articles overlap, the stronger their connection*". This type of scrutiny brings visibility to the most recent studies, not being restricted to the seminal publications' scope (Donthu *et al.*, 2021).

The results were presented in network, density and overlap graphs, generated by the VOSviewer software. The network graph displays networks of keywords, citations and authors (Eck and Waltman, 2014). In the density chart "items are indicated by a label in a similar way to visualizing labels" (Eck and Waltman, 2014). In the overlay graph, the visualization shows the number of times that keywords, citations and authors are repeated considering a temporal scale (Eck and Waltman, 2014).

Step 7: Results Analysis and Interpretation

Finally, the seventh step involves analyzing and interpreting the results obtained from both the performance indicators and the scientific mapping. This stage includes the identification of research trends, knowledge gaps, and emerging themes within the field (Donthu *et al.,* 2021), which are presented in the following section.

3. Results and Discussion

This section presents the findings from the bibliometric analysis of the scientific literature addressing the valuation of ecosystem services associated with shaded coffee cultivation systems. We begin by presenting the results of the performance analysis, providing the descriptive statistics of the retrieved publications, followed by the findings from the network analysis.

3.1. Performance analysis

The statistical analysis focused on presenting the absolute and relative frequencies of the retrieved publications, categorized by research field, publication year trends, and country of origin.

Figure 2 presents the ten leading research fields in which the retrieved publications were indexed. The majority of studies were published in journals classified under Environmental Sciences (25%), Environmental Studies (19%), Agronomy (16.9%), and Sustainable Science Technology (16.1%), which together account for 77% of the retrieved publications.

From a bibliometric perspective, the concentration of publications within a limited number of research fields reflects the disciplinary orientation and intellectual focus surrounding the topic. This pattern may be attributed to the fact that the research area is still considered emerging or niche within the broader scientific community. The results suggest that the topic has attracted greater attention from environmental, agricultural, and sustainability sciences, while showing comparatively limited engagement from fields such as economics, social sciences, and political studies.
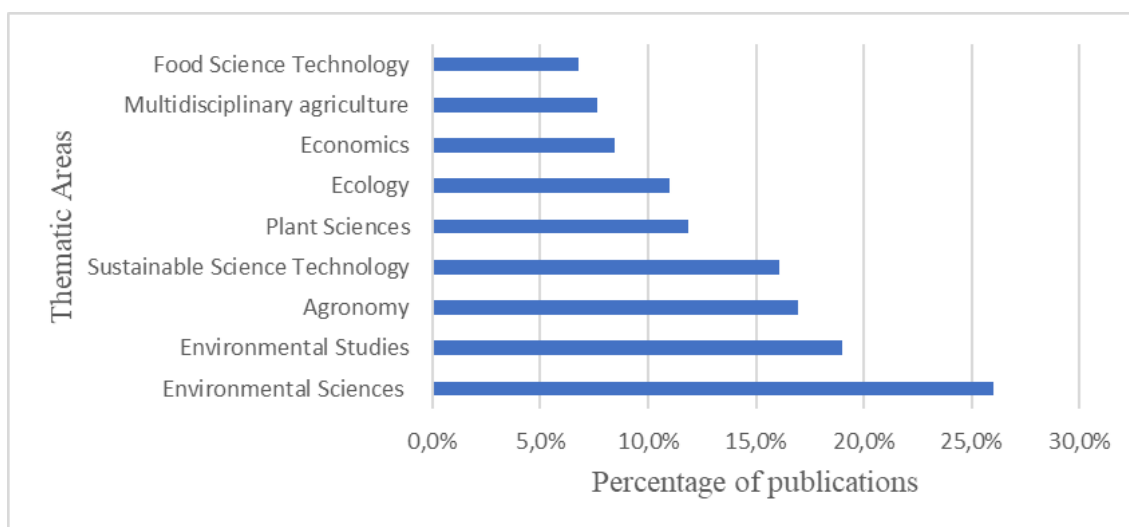
Figure 2: Publications by research field

The analysis of the annual publication frequency from 1995 to 2023 reveals an overall upward trend throughout the period, despite some year-to-year fluctuations. Until 2018, the number of publications remained below seven articles per year. From 2019 onwards, there was a consistent increase, reaching a peak of 19 publications in 2022. In 2023, a decline to 12 publications was observed, which can be attributed to the fact that the data represent only the first half of the year. Figure 3 illustrates the annual distribution of publications for the period 1995–2023.
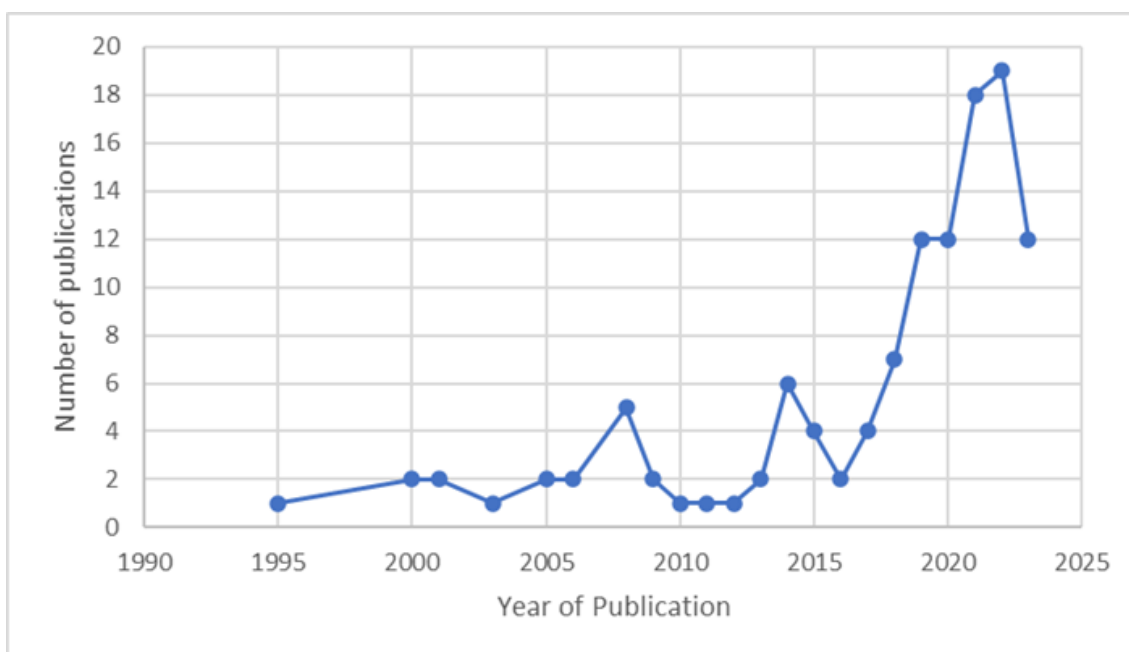
Figure 3: Scientific production between 1995 and 2023

The analysis of publication frequency over the period 1995–2023 reveals important insights into the scientific development of the research topic. Despite the relevance of shaded coffee farming for the maintenance of ecosystems, research on the topic is relatively recent (Santana *et al.*, 2021). The data indicate a gradual and sustained growth in academic interest, particularly from 2019 onwards, when a marked increase in the number of publications became evident, reaching a peak of 19 articles in 2022. This upward trend reflects the growing recognition of the importance of ecosystem service valuation in shaded coffee cultivation systems, especially in light of global discussions on sustainability, climate change, and agroforestry-based production models.

A total of 74 countries were identified as the origin of the retrieved publications. Table II presents the top 10 countries with the highest number of publications related to the environmental valuation of ecosystem services in shaded coffee farming during the period 1995–2023.

Table II: Top 10 countries publishing on study topic between 1995 and 2023

Order	Country	Number of publications
1	USA	24
2	Brazil	14
3	Spain	13
4	Germany	12
5	United Kingdom	10
6	Indonesia	10
7	Costa Rica	9
8	Mexico	9
9	Vietnam	9
10	Holland	8
	Total	**118**

Source: Authors (2023).

The distribution of publications shows a marked concentration in the United States (24 articles, 20%), followed by Brazil (14 articles, 12%) and Spain (13 articles, 11%). Notably, European countries as a group account for 48 articles, representing 40.6% of the total retrieved publications, highlighting the region's significant engagement with the research topic. Indonesia (10 articles, 8.5%), Costa Rica (9 articles, 7.6%), Mexico (9 articles, 7.6%), and Vietnam (9 articles, 7.6%) reflect an emerging research trend, likely driven by the growing need to address sustainable coffee production practices and the associated ecosystem service management challenges in these coffee-producing countries.

The leadership of the United States is likely associated with the country's robust research infrastructure and the availability of funding for interdisciplinary studies focused on sustainability and agroforestry systems (Donthu *et al.*, 2021). The strong

performance of European countries underscores the region's leadership in ecosystem service valuation research, likely influenced by the European Union's policy frameworks on environmental protection and sustainable agriculture. In South America, Brazil's leading role reflects both its prominent position as a major coffee producer and the growing engagement of the Brazilian academic community with themes related to agroecology, ecosystem services, and sustainable land use (Attman, 2022).

The findings reveal that the scientific literature addressing the valuation of ecosystem services in shaded coffee cultivation systems is largely concentrated within environmental, agricultural, and sustainability sciences. The upward trend in publications appears to be driven by countries with well-established research infrastructures and significant funding support for interdisciplinary research initiatives, which have positioned them as leading contributors to the field.

3.2. Network analysis

In this subsection, we conduct the network analysis to explore the structural relationships among publications based on keywords, citations, authorship patterns, bibliographic coupling, and co-occurrence of terms. This approach enables the visualization of the intellectual, social, and conceptual structures that characterize the research field (Donthu *et al.*, 2021).

The keyword analysis consisted of identifying the main research themes, conceptual trends, and core topics addressed in the scientific literature on the environmental valuation of ecosystem services in shaded coffee farming systems. The analysis of keyword frequency revealed the presence of 32 distinct terms, each represented as a note (circle) in the network visualization. Figure 4 illustrates the degree of interaction and connectivity among the identified keywords.

Although the overall focus of the publications is on the application of environmental valuation within shaded coffee systems, the most frequently occurring keywords emphasize themes related to ecosystem services and sustainability in this context. Notably, the terms "coffee" and "sustainability" appeared 14 times each, while "ecosystem services" appeared 11 times. The term "willingness to pay", commonly associated with economic valuation studies, appeared 4 times.

At least one publication in the dataset has explicitly explored the linkage between coffee and sustainability, as well as the relationship between shaded coffee systems and ecosystem services. Although the connection is still relatively tenuous, the co-occurrence of the keywords "coffee" and "willingness to pay" suggests an emerging correlation between coffee production and economic valuation approaches.

The keyword network analysis revealed the formation of three distinct clusters or thematic subareas. The first cluster concentrates on studies addressing agroforestry ecosystem services and climate change issues. The second focuses on agricultural practices and the shaded coffee production system itself. The third cluster highlights research concerning sustainable coffee quality and producers' willingness to pay for

biodiversity conservation. Together, these clusters reflect the multidimensional nature of the field, combining ecological, agronomic, and socioeconomic perspectives.
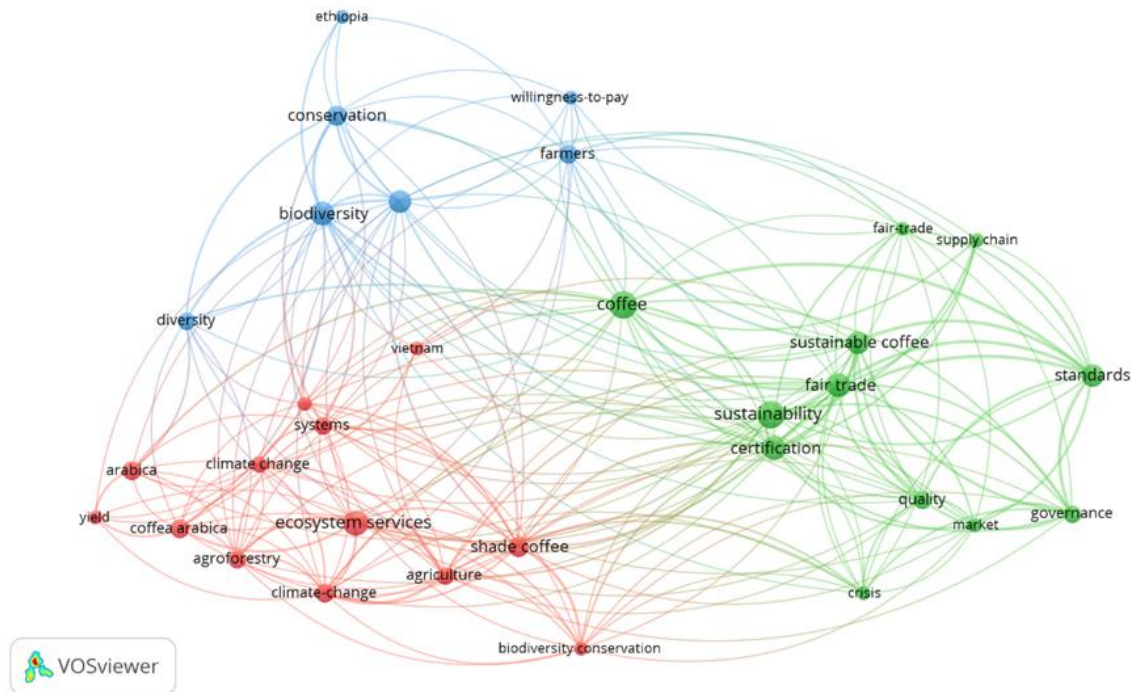

Figure 4: Visualization of keyword networks

The density visualization shown in figure 5 highlights the main research themes with the greatest scientific relevance, identified by regions of high density and centrality in the keyword network. These areas represent the topics that have received the most attention in the field. In contrast, keywords located in low-density and low-centrality regions indicate emerging or declining themes, reflecting underexplored areas and potential research gaps (Rojas-Lamorena *et al.*, 2022).

The density visualization presented in figure 5 highlights two main areas of thematic concentration in literature. The first is centered on sustainability certification and market mechanisms, as indicated by the high density of keywords such as "sustainability", "certification", "fair trade", and "sustainable coffee". This suggests that a significant portion of the research focuses on certification standards, fair trade practices, and their relationship with coffee production systems. The second area of concentration involves the ecological and agroforestry dimensions, represented by keywords like "ecosystem services", "shade coffee", "agroforestry", and "climate change", reflecting a strong emphasis on the environmental functions and benefits associated with shaded coffee cultivation.

In contrast, keywords such as "willingness-to-pay", "farmers", and "governance" appear in low-density and peripheral regions, indicating that economic valuation approaches, producer perceptions, and institutional governance frameworks remain

less explored within this research field. The presence of terms like "biodiversity", "conservation", and "climate change" in moderate-density areas suggests growing scientific attention to the ecological services provided by shaded coffee systems, but with opportunities for further integration of economic and policy dimensions.
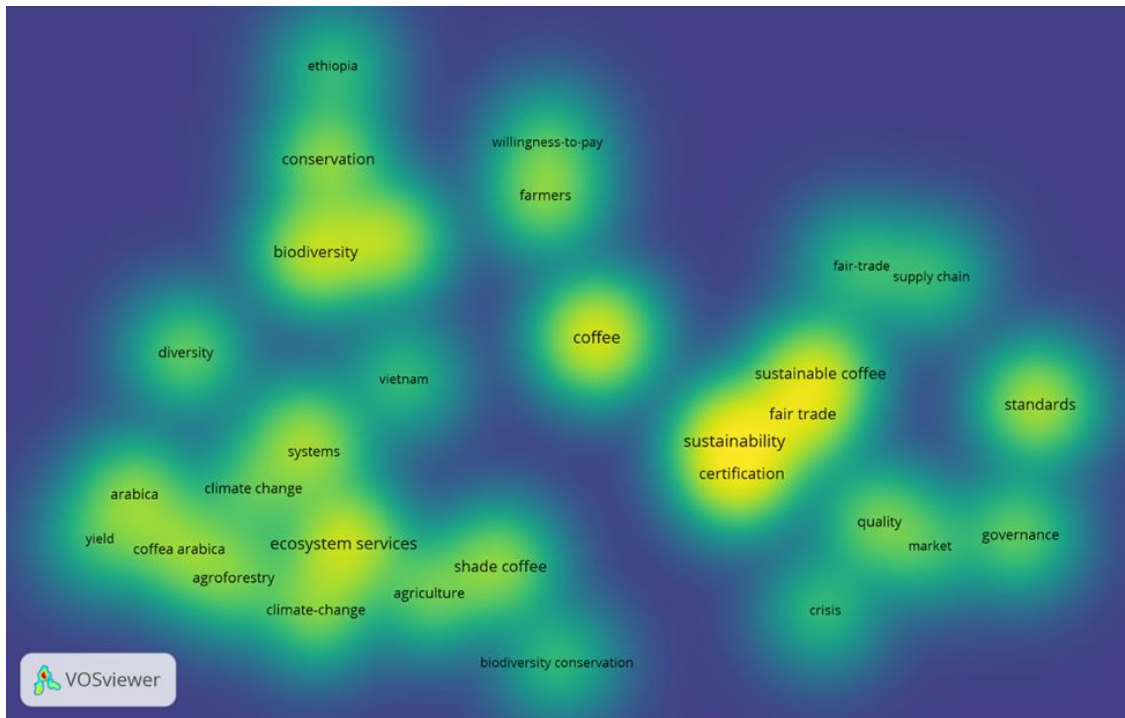

Figure 5: Keyword density visualization

The bibliographic coupling analysis, whose objective is to identify thematic similarities among publications based on shared references, revealed distinct clusters of authors who exhibit intellectual proximity within the research field. Figure 6 presents the results of the bibliographic coupling analysis, illustrating the thematic proximity among authors based on shared reference patterns.

As shown in figure 6, authors such as Perfecto (1996), Moguel (1999), and Muschler (2001) appear in the same cluster, indicating a strong thematic connection grounded in their mutual focus on technical aspects of shaded coffee cultivation. These works are recognized as seminal references within the literature analyzed, serving as foundational studies that have significantly influenced subsequent research on agroforestry coffee systems and their ecosystem services.

The bibliographic coupling analysis (Figure 6) reveals two distinct thematic clusters. The first, predominantly ecological and agroforestry-focused, includes authors such as Perfecto (1996), Moguel (1999), and Muschler (2001), who are frequently cited together and represent a consolidated knowledge base on biodiversity and ecosystem services in shaded coffee systems. The second cluster, with authors like Muradian (2005), Bacon (2005, 2008), and Raynolds (2007, 2009), reflects a research line centered on socioeconomic, governance, and certification issues. The limited interconnection between these clusters suggests a fragmented research field, with low

integration between ecological and socio-political-economic perspectives, a gap that future studies could address.
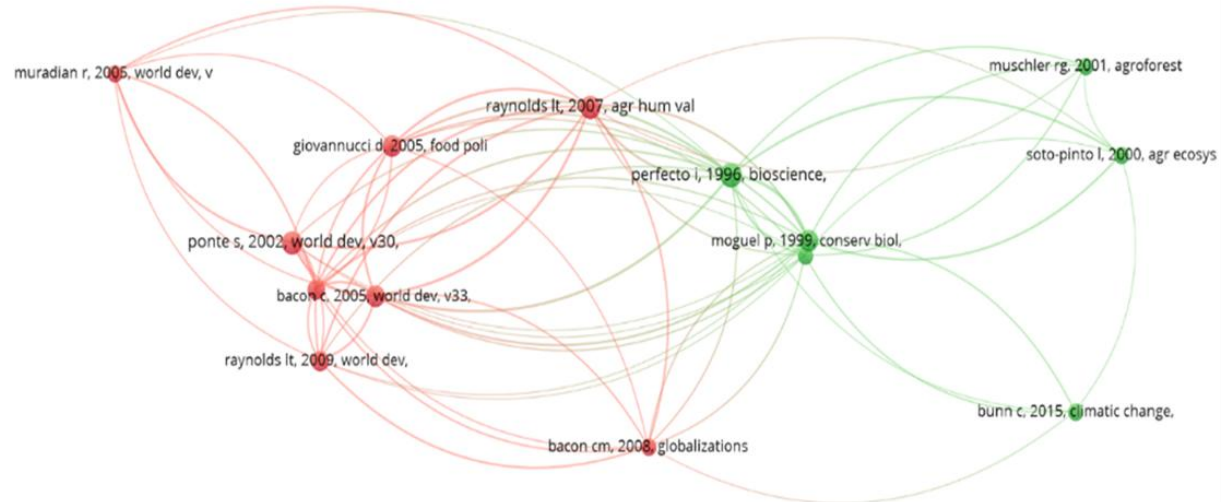

Figure 6: Visualization of co-citation networks

The analysis of the most cited publications over the last three decades reveals important patterns in the intellectual foundation of research on the environmental valuation of ecosystem services in shaded coffee systems. Table III presents the most frequently cited works from the past 30 years, along with their respective journals of publication.

Table III: Most Cited Publications and Their Respective Journals (1995–2023)

Authors	Paper Title	Journal	Number of citation
Perfecto I.	Shade Coffee: A Disappearing Refuge for Biodiversity	1996, Bioscience, v46, p598, doi 10.2307/1312989	14
Ponte S.	The 'Latte Revolution'? Regulation, Markets and Consumption in the Global Coffee Chain	2002, World Development, v30, p1099, doi 10.1016/s0305-750x(02)00032-3	12
Raynolds l.T.	Regulating Sustainability in the Coffee Sector: A comparative analysis of third-party environmental and social certification initiatives	2007, Agriculture and Human Values, v24, p147, doi 10.1007/s10460-006-9047-8	12
Moguel P.	Biodiversity Conservation in Traditional Coffee Systems of Mexico	1999, Conservation Biology, v13, p11, doi 10.1046/j.1523-1739.1999.97153.x	11

Authors	Paper Title	Journal	Number of citation
Bacon C.	A Bibliometric Analysis of the Scientific Literature on Fairtrade Labelling	2005, World Development, v33, p497, doi 10.1016/j.worlddev.2004.10.002	10
Daviron B.	The Coffee Paradox. Global Markets, Commodity Trade and the Elusive Promise of Development	2005, Coffee Paradox Globa	9
Raynolds l.T.	Mainstreaming Fair Trade Coffee: From Partnership to Traceability	2009, World Development, v37, p1083, doi 10.1016/j.worlddev.2008.10.001	9
Muradian R.	Governing the coffee chain: The role of voluntary regulatory Systems	2005, World Development, v33, p2029, doi 10.1016/j.worlddev.2005.06.007	7
Giovannucci D.	Standards as a new form of Social Contract? Sustainability Initiatives in the Coffee Industry	2005, Food Policy, v30, p284, doi 10.1016/j.foodpol.2005.05.007	6
Bacon C.M.	Are Sustainable Coffee Certifications Enough to Secure Farmer Livelihoods? The Millenium Development Goals and Nicaragua's Fair Trade Cooperatives	2008, globalizations, v5, p259, doi 10.1080/14747730802057688	6
Bunn C.	A bitter cup: climate change profile of global production of Arabica and Robusta coffee	2015, Climatic Change, v129, p89, doi 10.1007/s10584-014-1306-x	6
Muscular R.G.	Shade improves coffee quality in a sub-optimal coffee-zone of Costa Rica	2001, Agroforestry system, v51, p131, doi 10.1023/a:1010603320653	6
Soto-pinto l.	Shade effect on coffee production at the northern Tzeltal zone of the state of Chiapas, Mexico	2000, Agriculture Ecosystem & Environment, v80, p61, doi 10.1016/s0167-8809(00)00134-1	6
Van der Vossen Ham	A critical analysis of the agronomic and economic sustainability of organic coffee production	2005, Experimental Agriculture, v41, p449, doi 10.1017/s0014479705002863	6

Source: Authors (2023).

A notable concentration of highly cited publications and their leading authors is observed, with Perfecto's (1996) study standing out as the most cited reference within the dataset. The publication by Perfecto (1996), titled *"Shade Coffee: A Disappearing Refuge for Biodiversity"*, stands out as the most cited reference (14 citations), emphasizing the relevance of biodiversity conservation in shaded coffee landscapes.

Other highly cited studies include Ponte (2002) and Raynolds (2007), both addressing the regulation of sustainability, fair trade, and market structures within the global coffee

sector, highlighting the importance of socioeconomic and governance dimensions in the field. Moguel (1999) and Bacon (2005) also feature prominently, contributing to discussions on biodiversity in traditional coffee systems and certification impacts, respectively.

A significant number of these influential articles were published in high-impact journals such as *World Development*, *Conservation Biology*, *Agriculture and Human Values*, and *Bioscience*, reinforcing the interdisciplinary nature of the topic—spanning ecology, development studies, and agricultural sciences.

Figure 7 presents the results of the bibliographic coupling analysis by documents. The purpose of this analysis is to identify groups of publications that share similar reference patterns, thereby revealing thematic similarities and the current intellectual structure of the research field.

The bibliographic coupling analysis considered publications that shared at least two common references. Of the 92 retrieved publications, 68 met this criterion and were included in the network visualization, represented by nodes (circles) and linkages (Rojas-Lamorena *et al.*, 2022). The presence of shared references between articles suggests a thematic similarity in their content (Donthu *et al.*, 2021), indicating the strength of their intellectual connection and providing a useful tool for identifying recent studies relevant to the research topic.
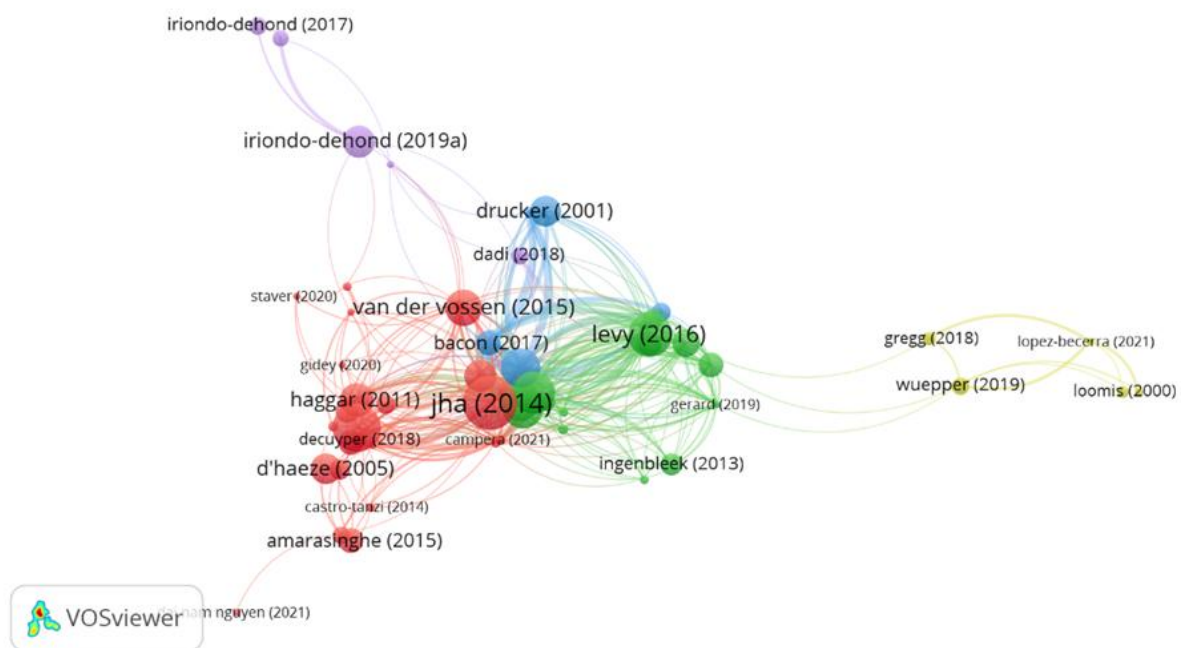

Figure 7: Bibliographic coupling by documents

Figure 7 presents the results of the bibliographic coupling analysis, revealing the formation of five distinct thematic clusters, each representing different research lines within the field of environmental valuation of ecosystem services in shaded coffee

systems. These clusters were identified based on the shared bibliographic references among the analyzed publications, following the methodological principles of thematic similarity mapping (Donthu *et al.*, 2021; Weinberg, 1974).

The first cluster (red) predominantly focuses on the agronomic and production aspects of shaded coffee, addressing topics such as crop management, yield, and agricultural sustainability. The second cluster (green) centers on ecosystem services and broader sustainability assessments, with an emphasis on environmental benefits and development-oriented perspectives. The third (blue) and fourth (mustard yellow) clusters are associated with economic valuation approaches, particularly studies focused on individual preferences, including themes such as willingness to pay and valuation methodologies. Finally, the fifth cluster addresses coffee as a commercial product, focusing on supply chain governance, certification processes, and market-related dynamics.

This clustering structure reflects the thematic diversity of the field while also highlighting a certain degree of fragmentation, with limited bibliographic overlap between ecological, socioeconomic, and market-oriented research strands.

In this study, a greater number of publications were linked through bibliographic coupling than through co-citation, reinforcing the observation that the field is in a phase of thematic expansion, with newer studies building on diverse reference sets. Notably, within the coupling analysis, clusters 1 and 2 (red and green) stood out for their strong focus on coffee farming sustainability, while the remaining clusters exhibited lower centrality and relevance to the specific theme of ecosystem service valuation, indicating thematic dilution in some areas of the literature.

Additionally, the results of the keyword co-occurrence analysis corroborate these findings by highlighting ecosystem services, coffee, and sustainability as central research themes, as demonstrated by their high frequency and strong network connections. The formation of three keyword clusters, as visualized in the network and density maps (Rojas-Lamorena *et al.*, 2022), confirms the conceptual concentration around ecological functions, agricultural management, and sustainability certification, further illustrating the fragmentation and the opportunity for interdisciplinary integration in this research domain.

Conclusion

This study presents the first bibliometric analysis focused on the environmental valuation of ecosystem services in shaded coffee cultivation systems, covering the period from 1995 to 2023. The results show that this is a recent and still fragmented field, with a significant increase in scientific production especially after 2019, reflecting the growing interest in topics related to sustainability, agroforestry, and ecosystem service valuation.

The performance analysis revealed a concentration of publications in the areas of Environmental Sciences, Environmental Studies, and Agronomy, with leading contributions from the United States, Brazil, and several European countries. The

keyword analysis confirmed the predominance of research focusing on ecosystem services, sustainability, and coffee agroforestry systems, while also pointing to underexplored themes such as economic valuation methods, governance frameworks, and farmer decision-making processes.

The network analyses (including co-occurrence, co-citation, and bibliographic coupling) revealed a fragmented thematic structure, characterized by limited integration between ecological, economic, and social science perspectives. The co-citation analysis highlighted seminal works on biodiversity conservation and certification, while the bibliographic coupling analysis showed the emergence of five distinct thematic clusters, reflecting the diverse but disconnected nature of current research.

Given these findings, the study highlights important knowledge gaps, especially concerning the integration of ecological, economic, and social approaches in the valuation of ecosystem services in shaded coffee systems. Future research should prioritize interdisciplinary studies, comparative regional analyses, and the development of valuation frameworks that inform both policy-making and sustainable coffee production practices.

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