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ANALYSIS OF BIOECONOMY ASPECTS IN AGRICULTURE AND BIOLOGICAL SCIENCES WITHIN AN INTERNATIONAL CONTEXT

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ABSTRACT

The objective of this research was to identify key aspects of the bioeconomy by examining multiple international studies, particularly in the areas of agriculture and biological sciences from 2008 to 2023. A bibliographic source analysis was conducted using Bibliometrix tools from R Studio and VOSviewer to analyze a database extracted from Scopus. During this period, the bioeconomy experienced significant growth in published research and its increasing relevance to the global scientific community. The number of citations and articles reflects the impact of bioeconomy research in academia, with countries such as Finland, Germany, and Italy standing out for their publication volume. The study identified three main categories defining current trends in the bioeconomy: sustainable development; forestry and production; and innovation, biomass, and biotechnology. There is a global pursuit of an environmentally friendly economic model. Therefore, the identified areas can inform future research and contribute to the development of public policies for specific contexts and the advancement of the bioeconomy.

Keywords: trends, circular economy, sustainable development, biotechnology.

INTRODUCTION

Biology and economics converge when addressing socioeconomic and environmental problems, giving rise to the concept of bioeconomy, which highlights the economic value of natural resources (Wang *et al*., 2022). The academic and scientific community has focused on developing an economy based on biological principles, which includes revaluing natural resources previously considered waste and unlocking their potential through an integrated and highly efficient approach. This makes it possible to reduce dependence on fossil fuels and mitigate the adverse effects of climate change (Carbonell *et al*., 2021). Contrary to the classical economic model that exploits agro-ecosystems for food and energy, the bioeconomic model seeks to reduce biological loss and pollution resulting from agri-food processes (Mougenot and Doussoulin, 2022).

This research summarizes the findings on the bioeconomy from various international bodies, such as the 2018 Global Bioeconomy Summit (GBS), which explored the concept of a bioeconomy through the lens of a sustainable economy that respects nature, generates economic benefits, and aligns with the Sustainable Development Goals. Similarly, the Economic Commission for Latin America and the Caribbean (ECLAC) highlights four pillars for the bioeconomy: sustainable development, action on climate change, social inclusion, and value-added innovations. The European Union views the bioeconomy as a crucial driver of green economic growth and the adoption of new technologies.

The bioeconomy concept is internationally relevant, yet its definitions vary by country or organization. This variation allows for the identification of common elements among these definitions and various international research studies. Analyzing these elements is essential for understanding the bioeconomy's scope and potential, as well as for developing effective strategies for its implementation to foster a more sustainable future (IICA, 2020). However, previous studies indicate that in Mexico, the momentum behind policies promoting the bioeconomy remains fragile (de la Cruz-Borrego and Caballero-Rico, 2021).

The objective of this research was to identify the key aspects of the bioeconomy by examining various international studies, particularly focusing on agriculture and biological sciences from 2008 to 2023. This timeframe was chosen because it marks the beginning of a notable increase in publications on the subject. The research hypothesizes that there are common analytical themes at the international level that have influenced the development of the bioeconomy.

MATERIALS AND METHODS

The analysis of bibliographic sources was carried out using two open-access programs: 1) VOSviewer, which is a software tool for constructing and visualizing bibliometric networks, and 2) Bibliometrix, which is an R Studio tool used to perform analyses. The analysis covered the period from April 2008 to April 2023. Data was collected from bibliographic records, which included authors, document titles, publication years, source titles, volume numbers and pages, citation counts, source and document types, publication stages, DOIs, and open access status. Additionally, bibliographic reports were generated, providing information on affiliations, series identifiers, PubMed IDs, publishers, languages, correspondence addresses, abbreviated source titles, abstracts, keywords, and indexed keywords for the documents. Funding details included information such as funding numbers, acronyms, sponsors, and funding texts.

Elsevier's Scopus was selected as the search engine due to its extensive coverage, which spans a wide array of disciplines and publications on a global scale. Other databases, such as Dimensions, OpenAlex, PubMed, and Lens, were not selected for specific reasons. For instance, PubMed is more focused on biomedical fields, while Lens and Dimensions, despite their broad scope, contain significant amounts of patent data and gray literature that do not align with the objectives of this study. Additionally,

OpenAlex is still in the early stages of adoption and lacks the comprehensive bibliometric tools that Scopus provides.

In April 2023, a search was conducted in the Scopus database using the keyword "bioeconomy" in article titles, limited to the fields of agricultural and biological sciences. This initial search identified 1792 unique documents. The dataset was then refined by narrowing the search to the subject area of agricultural and biological sciences, resulting in a total of 412 documents, which included articles, books, book chapters, and conference abstracts. From this collection, 184 articles were selected for analysis using the VOSviewer and Bibliometrix tools.

Analysis with Bibliometrix

The Bibliometrix package (http://www.bibliometrix.org) provides a comprehensive set of tools for conducting quantitative research in bibliometrics and scientometrics, all developed in the R programming language. Selected articles were sourced from the Scopus database. After downloading, the data was imported into the working environment, where a normalization process was implemented to address inconsistencies in author names, affiliations, and keywords. This process entailed unifying author names according to specific guidelines, standardizing affiliations using controlled vocabularies, and consolidating synonyms into keywords. Additionally, duplicate records were removed through algorithms that utilized DOI, titles, dates, and numerical fields. The analysis was ultimately conducted with tools such as word clouds and relationship maps, alongside the identification of sources, countries, and the most cited authors.

Analysis with VOSviewer

The bioeconomy analysis was conducted using VOSviewer software. The selected articles were exported in CSV format for further processing. The analysis involved several stages. First, a bibliographic map was created in VOSviewer, using the keyword co-occurrence option as the unit of analysis. Next, the data were imported, and the map was configured with a minimum threshold of six co-occurrences to identify general trends in the research (van Eck and Waltman, 2014). Fifty keywords were selected to facilitate a more detailed analysis, removing those that did not contribute relevant information to the study. Ultimately, the results concentrated on visualizing the co-occurrence network and the overlap of keywords, which facilitated the identification of research patterns within the field of bioeconomy.

RESULTS AND DISCUSSION

Scientific production, countries, authors, and journals

Scientific output for the bioeconomy within the fields of agriculture and biological sciences has demonstrated a growing trend since its inception. In 2008, there was only one article related to this topic, which increased to 41 documents by 2022 (Figure 1).

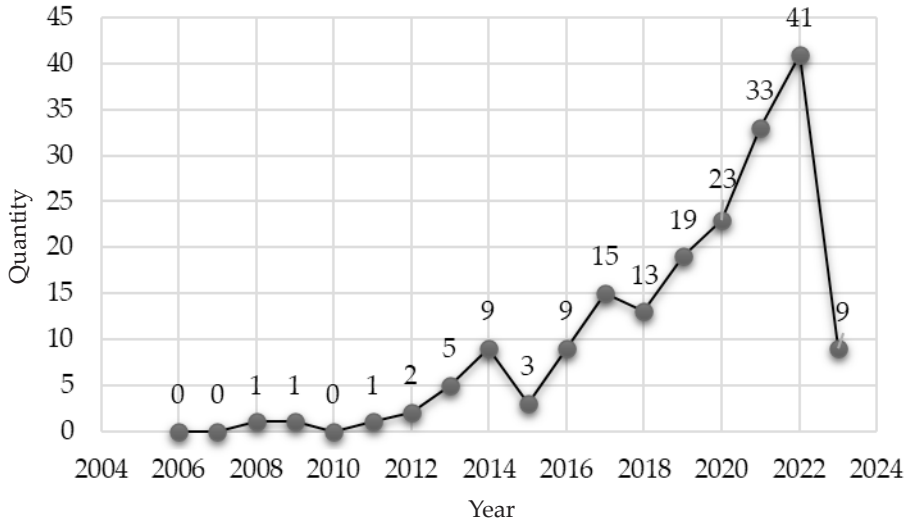

Figure 1. Scientific production of articles on bioeconomy (2008–2023) located in the Scopus database in the areas of agricultural and biological sciences.

A total of 3445 citations were found, with an average of 18.73 per article. The maximum number of citations was recorded in 2020 (675). The 10 most cited articles (Table 1) recorded a total of 1224 citations. These articles constitute 35.8 % of all scientific research in this emerging field, with an average of 122.4 citations per article.

With 187 citations, Arajo *et al*. (2021) holds the highest citation count. This research emphasizes the productive potential of algae in Europe and its role in promoting sustainable development. In second place is Dahmen *et al*. (2019), which has 179 citations and analyzes the organization of lignocellulosic biomass supply, which has great potential for the future as a regional biomass source for European lignocellulosic biorefineries. Lastly, Pülzl *et al*. (2014) examined the bioeconomy and its impact on forestry, along with classical discourses such as sustainable forest management, forest biodiversity, and climate change.

The analysis of countries with the highest citations of articles on the bioeconomy (see Figure 2) reveals that Finland leads with 772 citations, followed by Germany with 675 citations and Italy with 446 citations. A total of 54 countries have published related documents, but only two countries have published 30 or more articles (21.3 %). Seven countries fall within the range of 11 to 20 documents (30 %), while 45 countries have published 10 or fewer articles (48.5 %).

Finland and Germany are the countries with the highest number of published documents on bioeconomy (Table 2); however, Germany has more citations (772), with an average of 33.8 citations per article, compared to Finland, which has 675 citations and an average of 28.6 citations per article. This finding contrasts with Biancolillo *et*

Table 1. Most cited articles related to scientific research in bioeconomy in agriculture and biological sciences in the Scopus database.

Rank	Author (year)	Article title	Journal	Number of citations
1	Araújo *et al*. (2021)	Current status of the algae production industry in Europe: An emerging sector of the blue bioeconomy	Frontiers in Marine Science	187
2	Dahmen *et al*. (2019)	Integrated lignocellulosic value chains in a growing bioeconomy: Status quo and perspectives	GCB Bioenergy	179
3	Pülzl *et al*. (2014)	Bioeconomy - an emerging meta-discourse affecting forest discourses?	Scandinavian Journal of Forest Research	152
4	D'Amato *et al*. (2020)	Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs	Forest Policy and Economics	146
5	Lewandowski *et al*. (2016)	Progress on optimizing miscanthus biomass production for the European bioeconomy: Results of the EU FP7 project OPTIMISC	Frontiers in Plant Science	134
6	Kleinschmit *et al*. (2014)	Shades of green: A social scientific view on bioeconomy in the forest sector	Scandinavian Journal of Forest Research	130
7	Kröger and Raitio (2017)	Finnish forest policy in the era of bioeconomy: A pathway to sustainability?	Forest Policy and Economics	83
8	Pätäri *et al*. (2016)	Global sustainability megaforces in shaping the future of the European pulp and paper industry towards a Bioeconomy	Forest Policy and Economics	80
9	van Lancker *et al*. (2016)	Managing innovation in the bioeconomy: An open innovation perspective	Biomass and Bioenergy	77
10	Toppinen *et al*. (2018)	The future of wooden multistory construction in the forest bioeconomy – A Delphi study from Finland and Sweden	Journal of Forest Economics	76

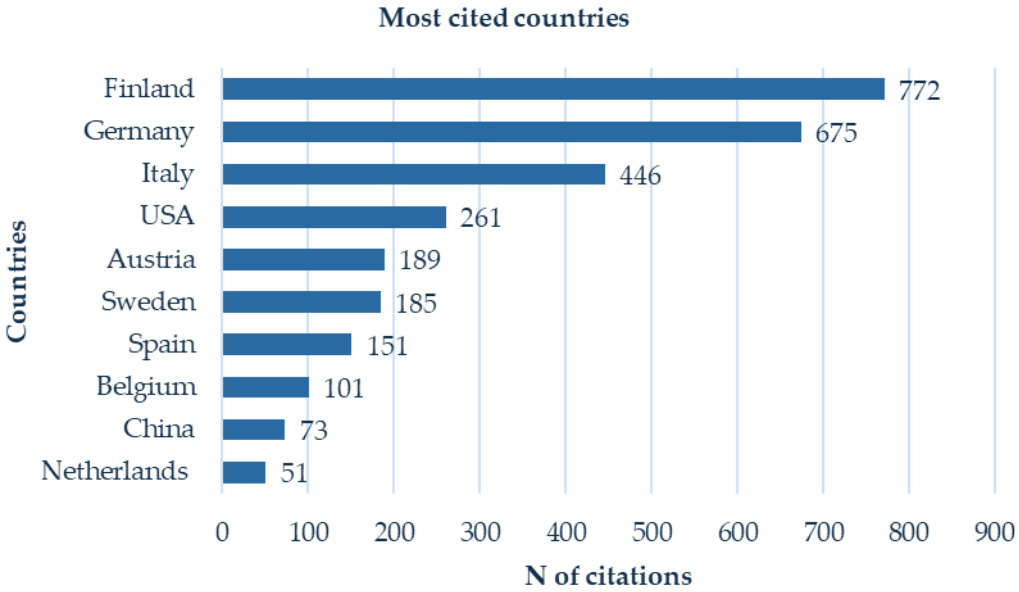

Figure 2. Countries of origin with the most citations of bioeconomy articles found in the Scopus database in the fields of agricultural and biological sciences (2008–2023).

Table 2. Average number of citations for countries with the highest number of articles published on the bioeconomy in the fields of agricultural and biological sciences (2008–2023).

Rank	Country	Number of citations	Average number of citations per article
1	Germany	772	28.6
2	Finland	675	33.8
3	Italy	446	34.4
4	USA	261	32.6
5	Austria	189	31.5
6	Sweden	185	37.0
7	Spain	151	25.2
8	Belgium	101	33.7

al. (2020), who reported that Finland and Canada have more scientific publications on bioeconomy.

As for the journals with the highest number of published documents (Table 3), Forest Policy and Economics stands out with 28 publications, followed by Forest with 13 scientific articles, and Biomass and Bioenergy with 11 documents.

Table 3. Journals publishing articles on bioeconomy in the fields of agricultural and biological sciences (2008–2023).

Rank	Journal	Number of articles	Citations	CiteScore	Impact factor	Science category	Position in the category	Quartile in category
1	Forest Policy and Economics	28	812	9.0	4.0	Forestry	4	Q1
2	Forests	13	77	4.4	2.4	Forestry	21	Q1
3	Biomass and Bioenergy	11	272	11.5	5.8	Energy and fuels	58	Q2
4	Land Use Policy	7	168	13.7	6.0	Environmental studies	25	Q1
5	GCB Bioenergy	6	229	10.3	5.9	Energy and fuels	57	Q2
6	AgBioForum	5	37			Agronomy and crop science	44	Q2
7	Bio-based and Applied Economics	5	75	2.8	1.8	Economics	241	Q2
8	Scandinavian Journal of Forest Research	5	370	3.0	1.8	Forestry	33	Q2
9	International Forestry Review	4	63		1.8	Forestry	40	Q2
10	Journal of Agricultural and Environmental Ethics	4	23	4.3	2.2	History and philosophy of science	11	Q1

Among the authors with the highest number of articles published over the last 15 years (Table 4), 10 studies by Toppinen A. stand out, followed by Korhonen J., with five publications. Toppinen *et al*. (2018) discuss sustainable development and the use of wood in construction, concluding that domestic consumers in Finland and Sweden are concerned about environmental sustainability.

Table 4. Leading authors in the publication of articles on bioeconomy in the fields of agricultural and biological sciences (2008–2023).

Rank	Author	Articles	Citations	Hirsch Index	Affiliated institution	Area of expertise
1	Anne Toppinen	10	529	49	University of Helsinki, Helsinki, Finland	Sustainability science, forest, economics, circular economy, bioeconomy and corporate responsibility
2	Jaana Elina Korhonen	7	151	18	Oak Ridge Institute for Science and Education, Oak Ridge, TN, USA	Forest-based sector, bioeconomy, sustainability, strategic management and mixed methods
3	Daniela Kleinschmit	4	341	23	University of Freiburg, Tennenbacher Str., Germany	Forest governance, bioeconomy, policy integration, participation and political communication
4	Satu Pätäri	4	195	21	School of Business and Management, Lappeenranta University of Technology, Lappeenranta, Finland	Strategic management, corporate responsibility, firm financial and innovation performance, Delphi method
5	Dalia D'Amato	4	162	26	University of Helsinki, Helsinki, Finland	Sustainability transformations
6	Alex Giurca	4	119	18	Chair of Forest and Environmental Policy, University of Freiburg, Tennenbacher Str., Freiburg, Germany	Bioeconomy, sustainability transformations, forest governance, timber trade, environmental communication
7	Stefan Bringezu	3	141	55	Wuppertal Institute for Climate, Environment and Energy, Germany	Socio-industrial metabolism, sustainability assessment, systems analysis, footprints, resource policies
8	Alessandro Paletto	4	31	29	Council for Agricultural Research and Analysis of the Agricultural Economy (CREA), Italy; University of Florence, Italy	Environmental impact assessment, environment, sustainability, natural resource management, ecology, biodiversity ecosystem ecology, mapping conservation and water quality
9	Markus Kröger	3	89	30	Department of Political and Economic Studies, Faculty of Social Sciences, University of Helsinki, Finland	Natural resource politics, social movements, Latin America, India and the Arctic
10	Isabella de Meo	3	29	23	Council for Agricultural Research and Analysis of the Agricultural Economy (CREA), Italy; University of Florence, Italy	Coarse woody debris; dead wood; forestry, sustainable development; environmental economics; circular economy, ecosystem service, land use, natural resource

Network display

A word cloud was generated showing the most frequently occurring words with a larger diameter or thickness (Figure 3), indicating the degree of interest among researchers (defined as strands). The words "bioeconomy," "forest," and "development" are displayed in the center, with the words "sustainable" and "production" shown to a lesser extent.

Figure 3. Word cloud on the concept of bioeconomy in the fields of agricultural and biological sciences (2008–2023) from the articles analyzed, created using Bibliometrix.

Main keyword co-occurrences

The relevance of words, determined by weighted percentages, is illustrated in the following values (Figure 4): bioeconomy (2.12 %), sustainable (0.9 %), production (0.73 %), development (0.72 %), and innovation (0.67 %). The remaining 96 identified words have lower representation, ranging from 0.15 to 0.34 %, with none exceeding 260 occurrences. Konstantinis *et al*. (2018) emphasize the fundamental role of technology in advancing the bioeconomy. The branched map includes the terms "environmental" and "agriculture" as relevant to the search. Abad-Segura *et al*. (2021) also talk about the words "transition" and "governance." They stress the need for support policies to help the economy move from one that wastes resources to one that uses them efficiently.

The relevance of the words "bioeconomy," "sustainable development," "forestry biomass," and "biotechnology," obtained in the VOSviewer program, showed a significant total link strength, primarily for the first three, with a strength greater than 200 (Table 5).

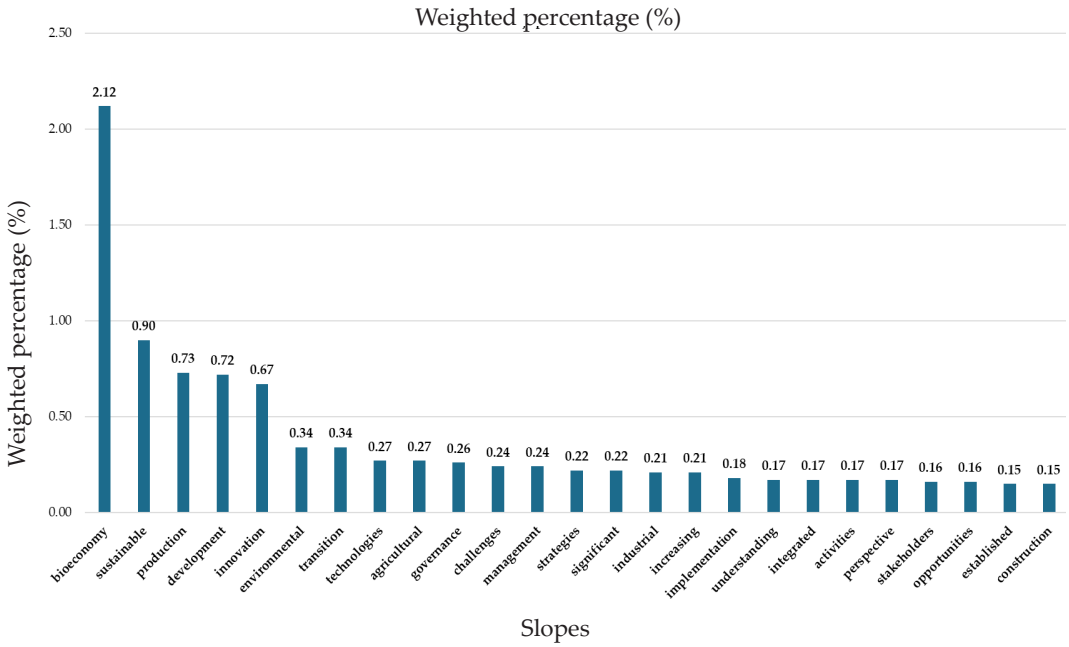

Figure 4. Co-occurrence of the top 25 keywords in bioeconomy articles in the fields of agricultural and biological sciences (2008–2023).

Table 5. Analysis of the top 25 co-occurrences of keywords from articles on bioeconomy in the fields of agricultural and biological sciences (2008–2023).

Rank	Key word	Co-occurrences	Total amplitude
1	Bioeconomy	92	318
2	Sustainable development	61	280
3	Forestry	47	239
4	Biomass	25	104
5	Biotechnology	18	69
6	Bioenergy	17	76
7	Economics	17	92
8	Circular economy	16	57
9	Climate change	16	88
10	Europe	14	79
11	Innovation	14	57
12	Biofuel	13	50
13	Circular bioeconomy	13	35
14	European union	13	78
15	Finland	13	77
16	Wood	13	69
17	Environmental economics	12	71
18	Timber	12	89
19	Commerce	11	68

Table 5. Continue.

Rank	Key word	Co-occurrences	Total amplitude
Rank	Key word	Co-occurrences	Total amplitude
20	Economic analysis	11	64
21	Forest management	11	77
22	Biodiversity	10	49
23	Development	10	56
24	Land use	10	58
25	Bio-based	9	54

Main aspects of the bioeconomy

Co-occurrence analyses reveal the relevance of the words "sustainable," "development," "forest," "production," "biomass," "innovation," and "biotechnology." However, these findings contrast with those found by Biancolillo *et al*. (2020), who identified three main concepts related to the bioeconomy: sustainable development, bioenergy production, and climate change mitigation. To contrast the analysis of keywords, a classification based on degrees was carried out (Table 6). The concept of bioeconomy is closely related to sustainable and development; in the second degree, to production and forestry; and in the third degree, to the concepts of innovation, biomass, and biotechnology.

Table 6. Classification of the main aspects of the bioeconomy in articles in the fields of agricultural and biological sciences (2008–2023).

Rank	Word	Software count
1	Bioeconomy	3
1	Sustainable	3
1	Development	3
2	Production	2
2	Forestry	2
3	Innovation	1
3	Biomass	1
3	Biotechnology	1

The evolution of the bioeconomy concept (Figure 5) shows a growing concern for climate change in 2018. In contrast, the European Union's research focus shifted in 2019 and 2020 to promoting innovation and public policies in agriculture, thereby supporting sustainable development. Finally, in 2021, the main research trends included the circular economy, development, crop production, and the creation of biorefineries.

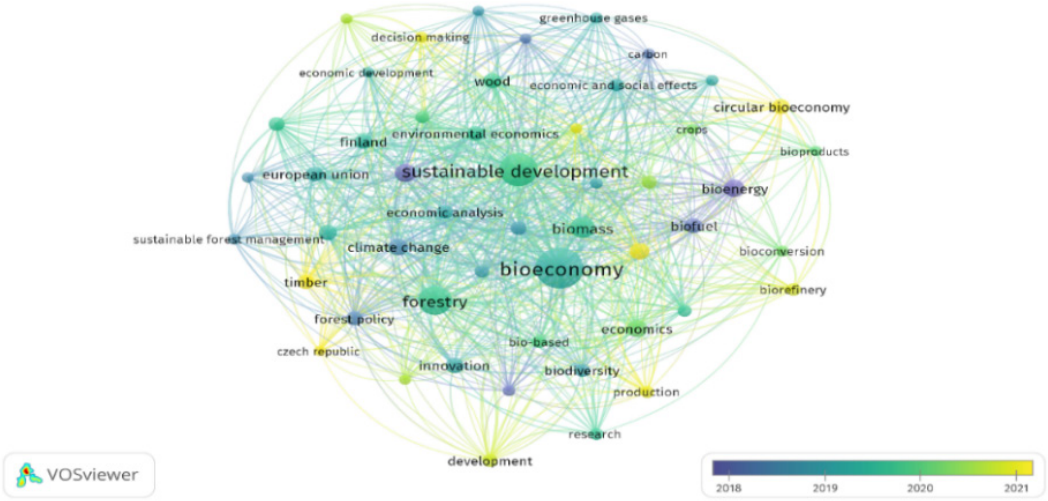

Figure 5. Overlay display of the evolution of the concept of bioeconomy from 2018 to 2021.

Analysis of the main aspects of the bioeconomy

First-degree concepts of importance

The words "sustainable" and "development" reflect the construction of the bioeconomy as a strategy that balances the sustainable conservation of natural resources with the promotion of economic development. The incorporation of sustainable practices in the use of biodiversity and natural resources guarantees the preservation of economic, environmental, and social assets for future generations, while promoting responsible economic development.

Sustainable. The pursuit of a balanced use of biological resources closely links the bioeconomy and sustainability. Given the concerns about climate change and responsible use of biological resources, it is crucial to develop models for the sustainable management of these resources (Mougenot and Doussoulin, 2022). The strategic integration of the bioeconomy and the circular economy promotes the sustainable use of natural resources through a systemic approach that enhances resource efficiency and minimizes environmental impact (Abad-Segura *et al*., 2021). The bioeconomy is an evolving economic model, characterized by varying degrees of technological progress (Papadopoulou *et al*., 2021).

Development. According to the Royal Spanish Academy (RAE, 2023), development is considered to be the "evolution of an economy towards better standards of living," while the United Nations (UN, 1997) describes it as "a multidimensional endeavor to achieve a better quality of life for all peoples."

Development in the bioeconomy is considered an essential concept in the advancement of agriculture, agribusiness, and various sectors involved in the production and utilization of bio-based raw materials (Wang *et al*., 2022). The bioeconomy helps development by creating new markets based on biological resources (Borrego and Rico, 2021), increasing value (Papadopoulou *et al*., 2021), and supporting regional development (Sanz-Hernández *et al*., 2019).

Sustainable development. The challenge of achieving sustainability while promoting economic growth and technological advancement was first introduced on a global scale in 1972, during the United Nations Conference on the Human Environment in Stockholm. It was established that "Man is entitled to freedom, equality, and the enjoyment of adequate living conditions in an environment of such quality that he can lead a dignified life and enjoy well-being, and he has the solemn obligation to protect and improve the environment for present and future generations" (UN, 1973).
The Global Bioeconomy Convention defines sustainable development as "the production, use, and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes, and services in all economic sectors, and move toward a sustainable economy" (GBS, 2018). The bioeconomy initially emerged as a strategy to utilize biological technologies, particularly biotechnology, more effectively. However, this concept has since evolved into a broader vision centered on sustainable development, aligning with the Sustainable Development Goals (IICA, 2020).

Second-degree concepts of importance

Currently, the production and management of natural resources are crucial to global well-being, which is why the bioeconomy vision presents significant opportunities in agri-food production. Production and forestry are the two areas that hold significant importance.

Production. Humanity is confronting significant challenges, including the depletion of fossil fuel supplies, the degradation of natural resources, and the acceleration of climate change. The bioeconomic model presents a transformative approach focused on developing renewable biological resources and converting them into high-value products. This strategy aims to address these challenges sustainably and effectively (Mougenot and Doussoulin, 2022). Achieving this goal requires both interdisciplinary and multidisciplinary approaches, as well as new insights into the use of by-products and waste. This shift drives the growth of bioenergy (Biancolillo *et al*., 2020) and biofuel production, paving the way toward fulfilling the Sustainable Development Goals (Nazari *et al*., 2021).

Forestry. Silviculture is a vital discipline within forestry sciences that focuses on forest management and regeneration. It utilizes established strategies and techniques for

regenerating tree species, based on knowledge of species autoecology as well as the ecology and dynamics of forests (Bannister *et al*., 2016). This approach has resulted in the publication of 225 documents by 567 organizations across 44 countries, concentrating on the forest bioeconomy. This bioeconomy is closely associated with three key concepts: sustainable development, bioenergy generation, and climate change mitigation (Biancolillo *et al*., 2020).

Third-degree concepts of importance

Aspects related to the concepts of innovation, biomass, and biotechnology have been identified, specifically focusing on tools for transforming waste from traditional production systems, now commonly referred to as biomass. The convergence of bioeconomy with these concepts creates a dynamic environment ripe for change. Innovations in developing processes and products not only diversify sources of raw materials, thereby reducing dependence on non-renewable resources, but also foster the emergence of new industries and job opportunities.

Innovation. The concept of innovation was first articulated by the esteemed economist Joseph Alois Schumpeter in his work "The Theory of Economic Development." He suggested that economic development is shaped by research and new knowledge, which in turn leads to innovations that create new techniques and production methods (Schumpeter, 2017). The Oslo Manual further defines innovation as the introduction of a new or significantly enhanced product, service, or good; a process; a marketing strategy; or a novel organizational method within a company's internal operations (OECD, 2005).

In the face of rapid climate change, it is vitally important to rethink the way biological resources are produced, consumed, transformed, stored, recycled, and disposed of. Advances in bioeconomy research and the integration of innovative technologies will enhance the management of renewable biological resources and foster the development of new markets for food and bioproducts (López-Feria and Barrero-Domínguez, 2021).

Biomass. The European Union defines biomass as "the biodegradable fraction of products, waste, and residues from agriculture, including vegetable and animal substances" (Olmo, 2018). Several centuries ago, during the Industrial Revolution, biomass was the primary source of energy worldwide. However, today, dependence on oil is evident. Due to environmental concerns, a return to cleaner energy sources is being considered to reduce pollution. The bioeconomy model leads to a change focused on a more sustainable economy, which can be achieved by accepting and implementing circular production models. The bioeconomy is becoming increasingly important as biomass is recognized as a key resource that integrates processes and enables the creation of high-value-added products (Carbonell *et al*., 2021). Within the Mexican framework, a wide range of by-products from agriculture, livestock, fisheries, forestry, and agro-industry can be utilized in the generation of biomass for

the sustainable production of biological resources and to meet the nation's energy demands (SADER, 2019).

Biotechnology. The connection between biotechnology and bioeconomy is essential, as biotechnology enables the management of biological organisms and processes for practical purposes. The bioeconomy benefits from biotechnology to enhance production efficiency, innovate in the development of new products, and use biological resources more effectively. It is argued that advances in biotechnology have driven the emergence of the bioeconomy (Konstantinis *et al*., 2018). Conversely, the bioeconomy offers an opportunity for the development of biotechnology (de la Cruz-Borrego and Caballero-Rico, 2021) and the creation of new products to enhance the efficient use of biomass generated in production processes, thereby promoting sustainability and innovation.

Europe is mapping out a unified path in the field of bioeconomy, based on research and technological innovation in multiple biotechnology applications (from de Besi and McCormick, 2015). Globally, several countries have integrated bioeconomy into their strategic policies (Carbonell *et al*., 2021). The three areas identified show us the lines of work pursued by the bioeconomy in the field of agricultural and biological sciences, requiring strategies and policies in different geographical areas (local, state, regional, national, and global), as well as the integration of multiple actors, both public and private, to achieve sustainable and permanent development for future generations.

Political importance of bioeconomy

Bioeconomy shares a common goal with sustainable policies, which is the need to establish a regulatory framework that promotes and facilitates practices to achieve an "environmentally friendly" economic model. Kröger and Raitio (2017) analyzed forestry policy in terms of sustainability goals and how to harmonize different dimensions. Bioeconomy emerges as a pillar in the search for sustainable and efficient economic growth to transition to a society with a strong dependence on renewable biological resources (Kleinschmit *et al*., 2014; Lombeyda, 2020). This scenario stipulates that related public policies should foster interdisciplinary approaches to study, innovation, and knowledge generation (Paltaki *et al*., 2021). The bioeconomy is becoming the central axis of progress, with continuous growth, which has already been adopted in the national development plans of several countries (Sanz-Hernández *et al*., 2019).

In this context, Mexico shows a degree of weakness in promoting public policies that encourage bioeconomy, as well as in making informed decisions regarding products derived from forest resources. At this turning point, it is crucial to capitalize on the opportunities presented by Mexico to develop a new economic model that aligns with environmental sustainability (de la Cruz-Borrego and Caballero-Rico, 2021).

CONCLUSIONS

Three general levels or strands were identified that outline the guidelines for bioeconomy in the field of agriculture and biological sciences: the first level is sustainable development; the second is forestry and production; and the third is innovation, biomass, and biotechnology. Intertwining these elements forms a holistic approach that aims to balance responsible biological resource exploitation with economic growth and sustainability. The analysis carried out confirmed that research on bioeconomy in the area of agriculture and biological sciences shares the same aspects.

One limitation of the study was that only scientific articles within the fields of agriculture and biological sciences were considered. Research on bioeconomy should be expanded in a more general context, and the findings should be linked to public policy to support more informed decision-making for the proper implementation of bioeconomy in various sectors of the economy.

The insights derived from this analysis can direct subsequent research, influence the formulation of context-specific public policies, and promote the advancement of the bioeconomy paradigm. The relationship between bioeconomy and public policy is crucial, as well-designed policies can promote the adoption of bioeconomic practices and foster markets centered on renewable biological resources. As the bioeconomy continues to evolve, it plays a vital role in seeking innovative and sustainable solutions to address both current and future challenges.

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REFERENCES

Abad-Segura E, Batlles-de la Fuente A, González-Zama MD, Belmonte-Ureña LJ. 2021. Implications for sustainability of the joint application of bioeconomy and circular economy: A worldwide trend study. Sustainability 13 (13): 7182. https://doi.org/10.3390/su13137182

Araújo R, Calderón FV, López JS, Azevedo IC, Bruhn A, Fluch S, Tasende MG, Ghaderiardakani F, Ilmjärv T, Laurans M, *et al*. 2021. Current status of the algae production industry in Europe: An emerging sector of the blue bioeconomy. Frontiers in Marine Science 7: 626389. https://doi.org/10.3389/fmars.2020.626389

Bannister JR, Donoso PJ, Mujica R. 2016. La silvicultura como herramienta para la restauración de bosques templados. Bosque 37 (2): 229–235. https://doi.org/10.4067/S0717-92002016000200001

Biancolillo I, Paletto A, Bersier J, Keller M, Romagnoli M. 2020. A literature review on forest bioeconomy with a bibliometric network analysis. Journal of Forest Science 66 (7): 265–279. https://doi.org/10.17221/75/2020-jfs

Carbonell SAM, Cortez LAB, Madi LFC, Anefalos LC, Baldassin JR, Leal RLV. 2021. Bioeconomy in Brazil: Opportunities and guidelines for research and public policy for regional development. Biofuels, Bioproducts and Biorefining 15 (6): 1675–1695. https://doi.org/10.1002/bbb.2263

Dahmen N, Lewandowski I, Zibek S, Weidtmann A. 2019. Integrated lignocellulosic value chains in a growing bioeconomy: Status quo and perspectives. GCB Bioenergy 11 (1): 107–117. https://doi.org/10.1111/gcbb.12586

D'Amato D, Veijonaho S, Toppinen A. 2020. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs. Forest Policy and Economics 110: 101848. https://doi.org/10.1016/j.forpol.2018.12.004

de Besi M, McCormick K. 2015. Towards a bioeconomy in Europe: National, regional and industrial strategies. Sustainability 7 (8): 10461–10478. https://doi.org/10.3390/su70810461

de la Cruz-Borrego JG, Caballero-Rico FC. 2021. Bioeconomía una alternativa para México. Análisis bibliométrico a la Web of Science. Dilemas Contemporáneos: Educación, Política y Valores 9 (1): 00046. https://doi.org/10.46377/dilemas.v9i1.2878

GBS (Global Bioeconomy Summit). 2018. Comunicado Cumbre Global de Bioeconomía 2018. Innovación en la bioeconomía global para la transformación sostenible e inclusiva y el bienestar. Berlín, Alemania. 20 p.

IICA (Instituto Interamericano de Cooperación para la Agricultura). 2020. Bioeconomía: potencial y retos para su aprovechamiento en América Latina y el Caribe: manual de capacitación. San José, Costa Rica. 115 p.

Kleinschmit D, Lindstad BH, Thorsen BJ, Toppinen A, Roos A, Baardsen S. 2014. Shades of green: A social scientific view on bioeconomy in the forest sector. Scandinavian Journal of Forest Research 29 (4): 402–410. https://doi.org/10.1080/02827581.2014.921722

Konstantinis A, Rozakis S, Maria EA, Shu K. 2018. A definition of bioeconomy through the bibliometric networks of the scientific literature. AgBioForum 21 (2): 64–85.

Korhonen J, Honkasalo A, Seppälä J. 2018. Circular economy: The concept and its limitations. Ecological Economics 143: 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Kröger M, Raitio K. 2017. Finnish forest policy in the era of bioeconomy: A pathway to sustainability? Forest Policy and Economics 77: 6–15. https://doi.org/10.1016/j.forpol.2016.12.003

Lewandowski I, Clifton-Brown J, Trindade LM, van der Linden GC, Schwarz KU, Müller-Sämann K, Anisimov A, Chen CL, Dolstra O, Donnison IS, *et al*. 2016. Progress on optimizing miscanthus biomass production for the European bioeconomy: Results of the EU FP7 project OPTIMISC. Frontiers in Plant Science 7: 1620. https://doi.org/10.3389/fpls.2016.01620

Lombeyda MB. 2020. Bioeconomía: una alternativa para la conservación. Letras Verdes. Revista Latinoamericana de Estudios Socioambientales 27: 13–30. https://doi.org/10.17141/letrasverdes.27.2020.3984

López-Feria S, Barrero-Domínguez B. 2021. Estrategia de bioeconomía y sostenibilidad en Dcoop a través de la Innovación. C3-BIOECONOMY: Circular and Sustainable Bioeconomy 2: 101–114. https://doi.org/10.21071/c3b.vi2.13745

Mougenot B, Doussoulin JP. 2022. Conceptual evolution of the bioeconomy: A bibliometric analysis. Environment, Development and Sustainability 24 (1): 1031–1047. https://doi.org/10.1007/s10668-021-01481-2

Nazari MT, Mazutti J, Bass LG, Colla LM, Brandli L. 2021. Biofuels and their connections with the sustainable development goals: A bibliometric and systematic review. Environment,

Development and Sustainability 23 (8): 11139–11156. https://doi.org/10.1007/s10668-020-01110-4

OECD (Organization for Economic Co-operation and Development). 2018. Oslo manual 2018: Guidelines for collecting, reporting and using data on innovation (Fourth edition). *In* The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing: Paris, France. https://doi.org/10.1787/9789264304604-en

Olmo IR. 2018. Directiva (UE) 2018/2001 del Parlamento Europeo y del Consejo de 11 de diciembre de 2018 relativa al fomento del uso de energía procedente de fuentes renovables. Diario Oficial de la Unión Europea 87: 141–144.

Paltaki A, Michailidis A, Chatzitheodoridis F, Zaralis K, Loizou E. 2021. Bioeconomy and livestock production nexus: A bibliometric network analysis. Sustainability 13 (22): 12350. https://doi.org/10.3390/su132212350

Papadopoulou CI, Loizou E, Melfou K, Chatzitheodoridis F. 2021. The knowledge based agricultural bioeconomy: A bibliometric network analysis. Energies 14 (20): 6823. https://doi.org/10.3390/en14206823

Pätäri S, Tuppura A, Toppinen A, Korhonen J. 2016. Global sustainability megaforces in shaping the future of the European pulp and paper industry towards a bioeconomy. Forest Policy and Economics 66: 38–46. https://doi.org/10.1016/j.forpol.2015.10.009

Pülzl H, Kleinschmit D, Arts B. 2014. Bioeconomy - an emerging meta-discourse affecting forest discourses? Scandinavian Journal of Forest Research 29 (4): 386–393. https://doi.org/10.1080/02827581.2014.920044

RAE (Real Academia Española). 2023. Desarrollo. Madrid, España. https://dle.rae.es/desarrollo?m=form (Retrieved: October 2023)

SADER (Secretaría de Agricultura y Desarrollo Rural). 2019. Biomasa, creación ecológica de energía. Gobierno de México. Secretaría de Agricultura y Desarrollo Rural. Ciudad de México, México. https://www.gob.mx/agricultura/articulos/biomasa-creacion-ecologica-de-energia (Retrieved: February 2025).

Sanz-Hernández A, Esteban E, Garrido P. 2019. Transition to a bioeconomy: Perspectives from social sciences. Journal of Cleaner Production 224: 107–119. https://doi.org/10.1016/j.jclepro.2019.03.168

Schumpeter JA. 2017. Theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle. Routledge: New York, NY, USA. 320 p. https://doi.org/10.4324/9781315135564

Toppinen A, Röhr A, Pätäri S, Lähtinen K, Toivonen R. 2018. The future of wooden multistory construction in the forest bioeconomy - A Delphi study from Finland and Sweden. Journal of Forest Economics 31: 3–10. https://doi.org/10.1016/j.jfe.2017.05.001

UN (United Nations). 1973. Report of the United Nations conference on the human environment. Stockholm, Sweden. 89 p.

UN (United Nations). 1997. Development program. A/RES/51/240. New York, NY, USA. 67 p.

van Eck NJ, Waltman L. 2014. Visualizing bibliometric networks. *In* Ding Y, Rousseau R, Wolfram D. (eds.), Measuring Scholarly Impact. Springer: Cham, Switzerland, pp: 285–320. https://doi.org/10.1007/978-3-319-10377-8_13

van Lancker J, Wauters E, van Huylenbroeck, G .2016. Managing innovation in the bioeconomy: An open innovation perspective. Biomass and Bioenergy 90: 60–69. https://doi.org/10.1016/j.biombioe.2016.03.017

Wang T, Yu Z, Ahmad R, Riaz S, Khan KU, Siyal S, Chaudhry MA, Zhang T. 2022. Transition of bioeconomy as a key concept for the agriculture and agribusiness development: An extensive review on ASEAN countries. Frontiers in Sustainable Food Systems 6: 998594. https://doi.org/10.3389/fsufs.2022.998594