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Decoding Bioeconomy: Trends and Definitions Through Bibliometric Insights

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ABSTRACT:
Bioeconomy is a field of study with major importance for economic systems, but its conceptualization still lacks a harmonized definition. To address this challenge and contribute to the understanding of the field of bioeconomy, the present research aims to identify the newest research tracks in the field of bioeconomy by conducting a bibliometric study within the interval 2010-2024.
The aim of the paper is to grasp all the relevant literature streams over the recent period by employing Dimensions as a database, with the aim to better define bioeconomy. The results are analyzed and visualized with the help of the VOSviewer software for term co-occurrence maps, co-authorship based on authors, institutions, countries and journals.
The findings of this paper may be valuable for researchers, academia, and policy makers interested in consolidation of the bioeconomy model to render a comprehensive system where bioeconomy can be better understood, defined and measured

Keywords: bioeconomy, sustainable development, bibliometrics, circular economy

1. Introduction

Bioeconomy is considered to be an economic system based on the use of biological renewable resources and their conversion to value-added products (McCormick & Kautt, 2013). It is founded on the production of renewable biological resources from land and sea (forestry, agriculture, zootechnics, fisheries, organic waste, etc.) which are converted to food and feed, energy, and other bio-based products to be used in all economic sectors (European Commission, 2012; Momete, 2017; Baranano et al, 2021). Bioeconomy is perceived by some scholars as being an important component of the green economy (Vivien, 2019) but also having an important role in implementing circular economy (Birner, 2018).

The economy based on bioeconomic concepts addresses important challenges ranging from scarcity of natural resources, the dependence on fossil fuels and correlated pollution, to food and feed security, greenhouse gases emissions (GHG) and climate change. However, the concept raised also criticism and concern for world food safety, the interests of big companies but also the possible greenwashing disguise (Stephenson & Damerell, 2022).

There is no harmonized definition of the bioeconomy (U.S. Department of Agriculture, 2024; Albinelli et al, 2024) and the above descriptions reflect the positions of international institutions or a particular country's views. Bioeconomy strategies were mainly based so far on national attempts (Bößner & al, 2021) and international/regional

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cooperation in this field would better support the development of bioeconomy. A standardization of bioeconomy is difficult to achieve, as the countries are diverse in resource endowment, economic development, consumption patterns, existing industrial structures and value chains. For countries with similar natural resources or conditions would be easier to shape their bioeconomy strategies on the same pillars. For instance, countries with a strong agricultural power, like China, Brazil, USA, would be more focused on the biomass, biofuels and waste valorisation from agriculture residues and food processing. Other countries rich in forests, like Finland, Indonesia, Russia would prioritize sustainable forestry, wood-based biochemicals, biorefineries and bioenergy from forest residues. The countries located on coasts, like New Zealand, Norway, Thailand, would be more focused on marine biotechnology, sustainable aquaculture and valorisation of fisheries waste. Countries with consistent waste streams, like India, Israel, Switzerland would place an emphasis on circular economy, waste-to-resource technologies and bio-based products. The national interpretative frameworks show that bioeconomy as a term can be fluid, therefore it can be practically implemented into policy agendas considering the national contexts, belonging both to Global North and Global South. Despite the apparent diversity, there is a common background in bioeconomy as all countries face some challenges and need shared policies, regional/supranational/international funds, regardless of the emphasis on the type of biotechnology, based on land or water. Nevertheless, international collaboration is essential for the bioeconomy development, as it requires policy integration across sectors, but also across countries, regions and citizens. This horizontal and vertical policy integration would better contribute to the achievement of sustainable development goals (Gould & al, 2023) and the development of equitable bioeconomy strategies.

To start collecting information for a standard definition, this paper aims to map the scientific field of bioeconomy with a bibliometric analysis, attempting to shed a light on its complexity and interdisciplinary convergence. As bioeconomy is not a static field, it needs a constant update and a bridging of the current views under the three pillars of sustainable development (economic, social and environmental). This paper updates information in the dynamic field of bioeconomy, including other bibliometric studies (Mougenot & Doussoulin, 2022; Gould & al, 2023) or expert's perspectives (Dietz & al, 2023) and contributes to the vivid debate about a sustainable bioeconomy where the needs of both Global North and Global South should be considered.

To address the challenges and contribute to the understanding of the field of bioeconomy and better define it, the present research aims to identify the newest literature streams in the area of bioeconomy, by addressing the next research questions (RQ):

- RQ1: How has bioeconomy core knowledge evolved during time?
- RQ2: Which are the topics of research associated with bioeconomy?
- RQ3: Which are the most influential researchers, institutions/countries and journals in the field of bioeconomy?
- RQ4: Which are the key elements needed to comprehensively define bioeconomy?

The four research questions were answered with the help of a bibliometric analysis, which is commonly applied to study scientific literature by analysing the research

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effect, by identifying the terms most frequently employed, the authors and their collaboration networks (Leydesdorff & Milojevic, 2015; Momete, 2024). This bibliometric analysis allows the grasping of the main characteristics and dynamics in the field of bioeconomy by exploring of large scholarly literature presenting the current state, trends of a given topic and existent connections within the explored field by using network analysis focused on relationship between elements, proving to be a transparent, reproducible and no-biased method of investigation (Virgolino & Holden, 2025; Cardoso et al, 2023).

The rest of this paper is organized into the following sections: section two offers the theoretical background, section three illustrates the methodology by presenting the study design and research steps, section four contains the results and discussion of their implications and section five outlines the conclusions and the future research directions.

2. Theoretical Background

Bioeconomy is based on different perspectives and three lines of thought may be connected to it which have evolved during time, ranging from strong sustainability principles (type I) to softer sustainability (types II and III):

- Type I - Bioecology: ecological perspective of economy developed by Nicholas Georgescu-Roegen in the '70s (Georgescu-Roegen, 1977). The term bioeconomics was used for the first time by the Romanian born mathematician and economist Georgescu-Roegen who considered that the basic laws of nature are incompatible with unlimited growth. He considered that all economic processes can be rooted in biological resources and analysed the evolution of technologies, which he very suggestive named "Promethean technologies", that led to ecological problems and fossil-fuel depletion.
- Type II - Bioresources: the resource substitution perspective developed by the Council of the European Union (EU) in the 2000s (Council of the European Union, 2017) which aims to replace fossil fuels with fuels derived from biological resources by developing biorefineries, small-scale methanizers (Mougenot & Doussoulin, 2022) and other industrial products like biopolymers and chemicals.
- Type III - Biotechnology: a biotechnological perspective developed by Organization for Economic Cooperation and Development (OECD) in mid-2000s (Organization for Economic Cooperation and Development, 2009) in which biotechnology plays an essential role, and the biological resources are used to develop economies.

There is no universally accepted definition of the bioeconomy (U.S. Department of Agriculture, 2024; Albinelli et al, 2024), as different organizations, nations and scholars emphasize various aspects depending on their priorities, placing an emphasis on sustainability, biotechnology, circular economy, and so on. To craft a well-rounded definition that captures all necessary key elements, this paper starts by analysing the actual emphases on bioeconomy. Various emphases were considered for bioeconomy, reflecting national or institutional views, as presented by table 1. According to the Food and Agriculture Organization of the United Nations (FAO) dashboard on bioeconomy 23

countries have already dedicated strategies to bioeconomy, while other 15 are in the process of developing a strategy (Food and Agriculture Organization of the United Nations, 2025).

Table 1: Comparison of different views on bioeconomy

Organization	Key elements	Emphasis	Source
Federal Ministry for Education and Research, Germany	• production, exploitation, and use of biological resources, processes, and systems; • provision of products, processes, and services within a sustainable system	• sustainable use • cross-sectoral • systemic integration	"National Research Strategy BioEconomy 2030" (Federal Ministry for Education and Research, 2011)
International Advisory Committee of the Global Bioeconomy Summit, Germany	• utilization of biological resources, processes, and principles • knowledge-based production • sustainable provision of goods and services	• across all economic sectors (RD&I agriculture/forestry/marine sectors, food, healthcare, biotechnology, etc) • international approach	"Communique Global Bioeconomy Summit 2015" (Communique Global Bioeconomy Summit, 2015)
European Commission	• sectors and systems relying on biological resources; • alignment with sustainable and circular; • food and nutrition security, natural resource management, reduced dependence on non-renewables	• sustainable use • circularity • broad scope • policy alignment	"EU Bioeconomy Strategy" (European Commission, 2018)
Summit G20	• sustainable use of renewable biological resources; • production of goods and services; • respecting ecosystem limits	• sustainable use • broad scope • environmental responsibility • circularity	"G20 Initiative on Bioeconomy" (G20 Initiative on Bioeconomy, 2024)
Food and Agriculture Organization	• production, utilization, conservation, and regeneration of biological resources; • related to science and technology innovation • sustainable solutions across all economic sectors	• integrated resource management • sustainable use • innovation-driven	"Bioeconomy for sustainable food and agriculture" (Albinelli et al, 2024)

Despite its name linked to economy, the bioeconomy is powered by industry and may be a great contributor to achieving the United Nations Sustainable development goals

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from Agenda 2030 (United Nations, 2015) by operating on all the pillars of a sustainable future: economic, social and environmental (United Nations, 2023). Bioeconomy may be fuelled by many industries and combining biology with chemical industries, environmental engineering and information technology can lead to new products, processes and novel applications for a foreseen or surprising future. However, the application of traditional ways of manufacturing of bioeconomy must evolve and challenges overcome as new ways of thinking must be in place for this complex and interdisciplinary territory. Moreover, policies and strategies supporting bioeconomy must be better formulated to address societal needs and build a sustainable and resilient economy (Philip et al, 2022).

Demonstrating its actual importance, the EU is underway to develop a new strategy on bioeconomy, programmed to be released by the end of 2025. To this end the European Commission launched a consultation on 31 of March 2025 (European Commission, 2025) to better support European Union's businesses rooted in sustainability and circularity which are respecting the environment and are meeting the climate requirements.

3. Methods

Study design is based on bibliometric analysis which aims to answer the four research questions formulated above using the data provided by Dimensions and analysed by VOSviewer. This paper uses bibliometric analysis of scientific literature within the interval 2010-2024 to grasp all the relevant literature streams after the formulation of all three types of perspectives in the field of bioeconomy. An inquiry performed in February 2025 on the Dimensions database (Digital Science, 2018) provided suitable answers to this research's questions. The results were exported to VOSviewer software (version 1.6.20) (van Eck & Waltman, 2010; van Eck & Waltman, 2023) and further analysed for term co-occurrence map, co-authorship and citation based on researchers, institutions and journals.

To grasp the best relationship within the research community several types of analyses were performed which are presented in table 2.

The investigation methodology followed the next stages:

- Step 1: selection of dataset based on Dimensions; Keywords: "bioeconomy OR bio-economy". Time span: 2010-2024 (title and abstract). Types of selected publications: articles, chapters, books, preprints, proceedings, monographs published in English (8374 results). The selected publications did not consider policy documents and grants.
- Step 2: analysis of the data extracted from Dimensions which show changes in the field of bioeconomy.
- Step 3: export of data from Dimensions to VOSviewer for the building of a co-occurrence map of terms and the analyses based on co-authorship and citation.
- Step 4: selection of the most relevant elements to be included in a comprehensive yet concise definition of bioeconomy which has the potential to be universally accepted.

Table 2: Types of analyses for identifying research trends in bioeconomy

Analysis	Technique	Unit	Visualization
Performance analysis	Descriptive statistics (created by using Dimensions and MS Excel)	Number of publications/year Academic impact/year	Scatter plot
		Types of publications	Tree map
		Number of publications/SDGs Number of publications/research categories Number of publications/engineering fields The most influential engineering research areas in the field of bioeconomy	Column chart
Network analysis/clusters	Co-occurrence map (created by using VosViewer)	The most relevant terms	Network visualization
	Co-authorship Co-citation (created by using VosViewer)	The most influential researchers The most influential institutions & countries The most influential journals	Cluster analysis

To answer RQ1 the evolution in the number of publications on each year, their academic impact, and the contribution to each sustainable development goal (SDG), for both closed and open access, were considered and 8374 publications were taken into consideration. For RQ2 a co-occurrence map of terms based on text data extracted from Dimensions was performed in VOSviewer, in network visualization, which allows to point out the most influential topics of research. To answer RQ3 the co-authorship analysis and citation analysis were performed, showing the most influential researchers, institutions and journals in the field of bioeconomy. For RQ4, the key elements from the most cited articles were considered to better identify a definition which is concise but comprises all the essential elements of bioeconomy.

4. Results and discussion

From Dimensions database 8374 academic publications referring only to articles, chapters, edited books, monographs, preprints and proceedings were extracted and the types of publications are depicted in figure 1. Most of the publications are open access (4509), present in all types of open access: gold, hybrid, green and bronze. The research did not consider other types of results, such as policy documents and grants to avoid popularity of funding language or an artificial visibility of some buzzwords used in policies and public communication.

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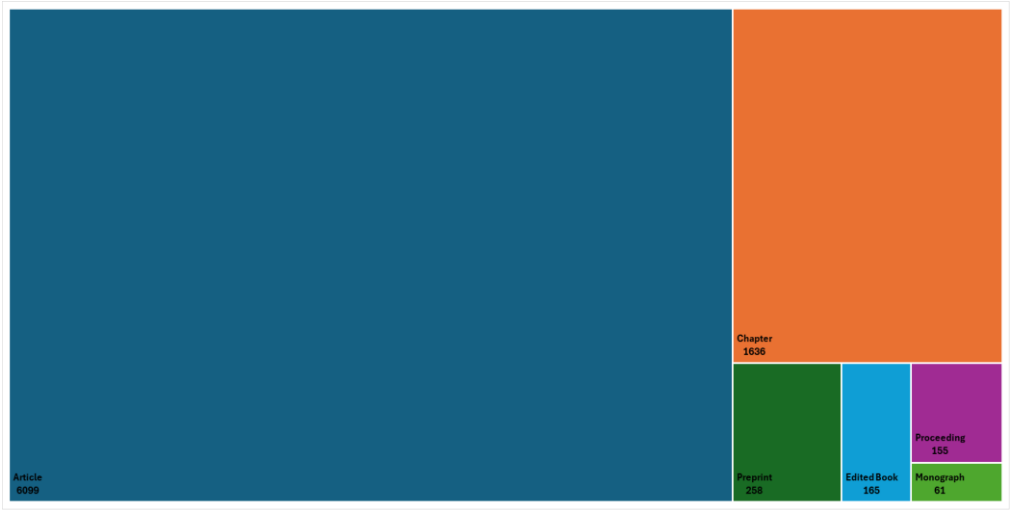

Figure 1. *Types of publications for bioeconomy (processed from Dimensions database)*

From 35 publications in 2010 to 1621 papers in 2024, the field constantly and significantly grew resulting in a 46-fold increase (see figure 2). Starting from 35 publications in 2010, reaching 135 in 2015, the year of the adaptation of the 17 SDGs, and exploding to 1375 in 2022, and to 1621 in 2024, the field shows an increased alignment with the SDGs to be achieved by 2030. The academic impact also increased spectacularly, from 16 citations in 2010 to 42,960 total citations in 2024, revealing an expanding interest in the field of bioeconomy.

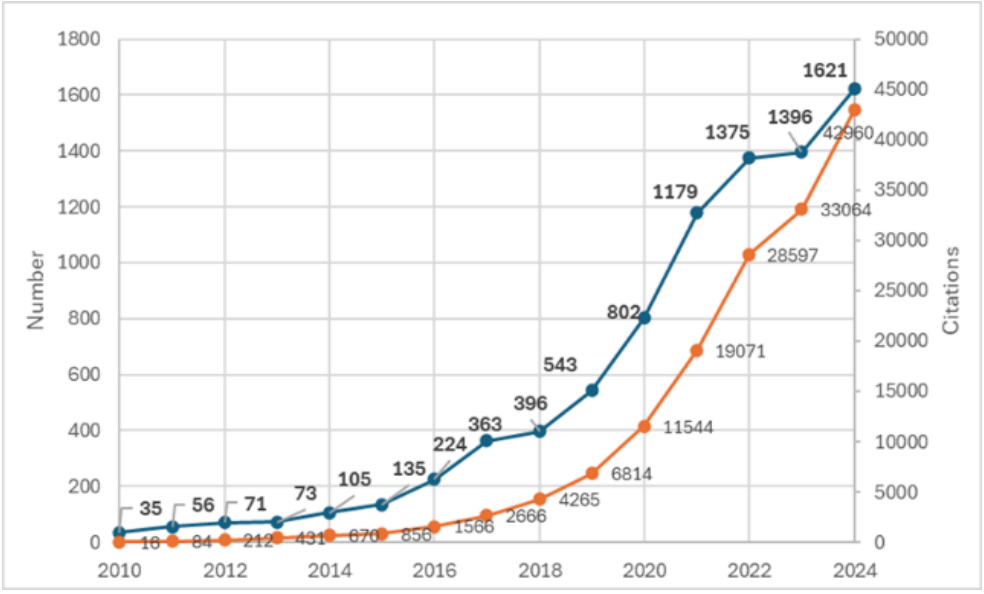

Figure 2. *Evolution of the number of publications and the academic impact in the interval 2010-2024 in the field of bioeconomy (processed from Dimensions database)*

In terms of contribution to the SDGs, figure 3 points out the contribution of bioeconomy field on all 17 SDGs, with a larger contribution coming from SDG12 (sustainable production and consumption), with 2737 publications and SDG 7 (clean and affordable energy), with 1771 publications.

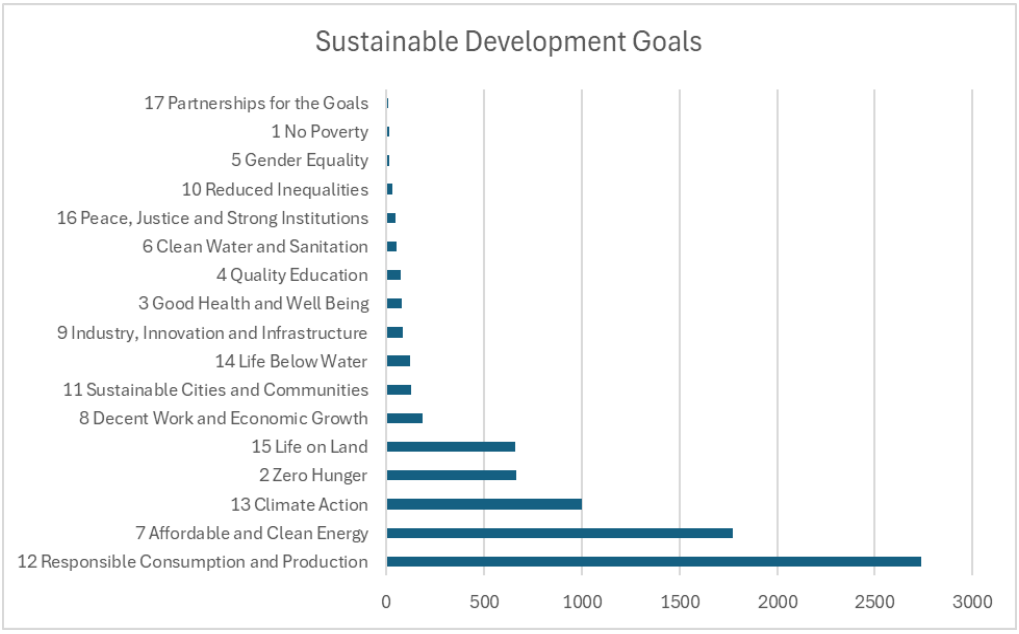

***Figure 3**. Contribution of bioeconomy to each sustainable development goal (processed from Dimensions database)*

To clearly capture the complexity and interdisciplinarity of bioeconomy, figure 4 shows the contributions to the field, by research categories, in accordance with ANZSRC 2020 (Australian Bureau of Statistics, 2020). The bars show the number of contributions to each research category, with larger contributions from field 31 (biological sciences), with 2647 publications, and field 40 (engineering), with 1703 publications. For each of the 22 research categories, further analysis is possible on all subfields, but, considering the confinement of this paper, the analysis only in field 40 is shown in figure 5. The most influential engineering research areas in the field of bioeconomy are chemical engineering (4004) and environmental engineering (4011).

The data from Dimensions database was imported to VOSviewer where it was further analyzed. The analyses allow the identification of networks showing clusters of keywords, authors, journals and organizations. The connections present in the network show the intensity of co-citation and citation (van Eck & Waltman, 2023). The topics of research associated with bioeconomy are revealed by the co-occurrence map of terms created by using VOSviewer on the data extracted from Dimensions. The most relevant 100 terms were extracted from 48,268 keywords which are grouped in four clusters, presented with different colours in figure 6. The data is normalized by association strength, and there are 1291 links, with 3405 total link strength, considering a full counting.

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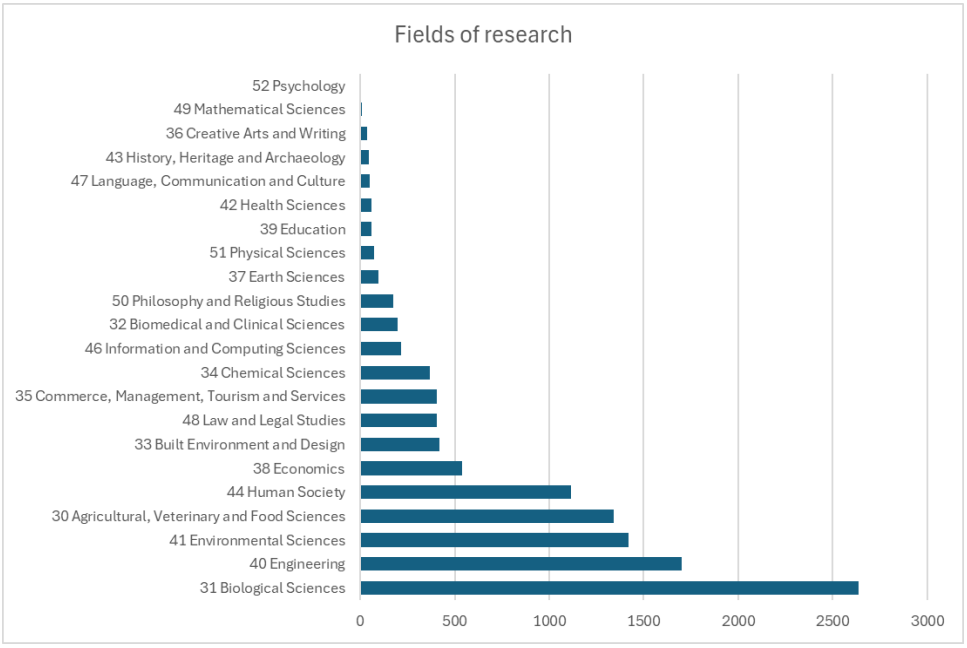

Figure 4. *Contribution of bioeconomy to different research categories (processed from Dimensions database)*

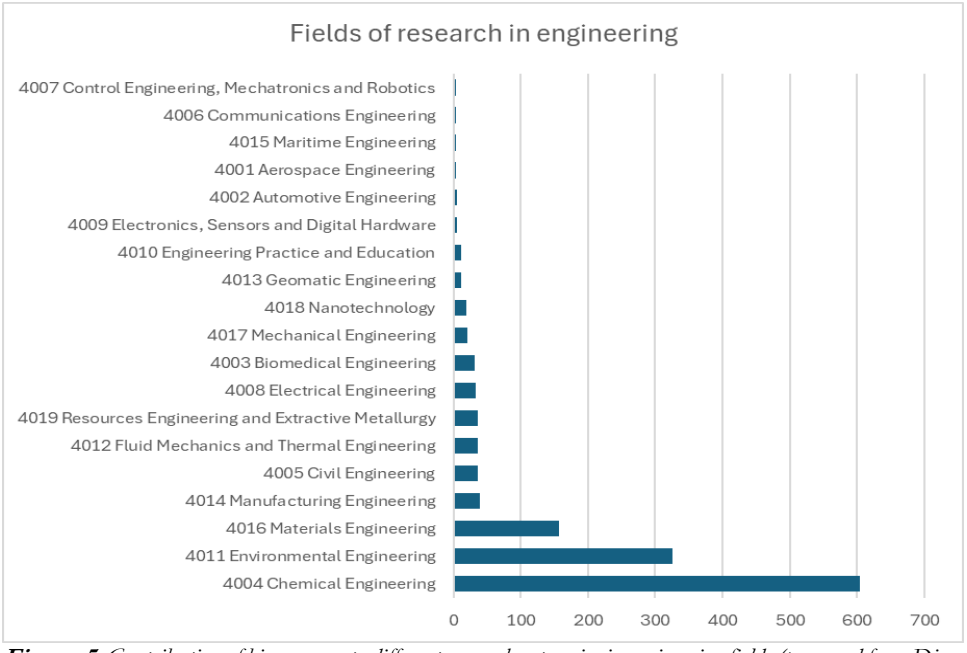

Figure 5*. Contribution of bioeconomy to different research categories in engineering fields (processed from Dimensions database)*

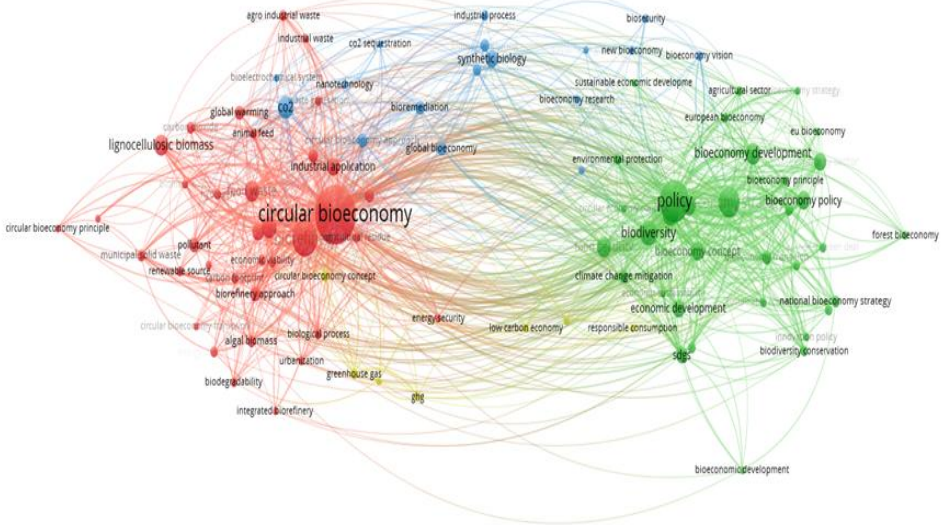

Figure 6. *Co-occurrence map of the most relevant terms for the field of bioeconomy. (data retrieved from VOSviewer)*

A future research agenda may include the most relevant topics in the field: circular bioeconomy, biorefineries, bioeconomy strategy and policy. The most relevant term to bioeconomy appears to be circular economy, which has 577 occurrences and 86 links, as revealed by figure 7.

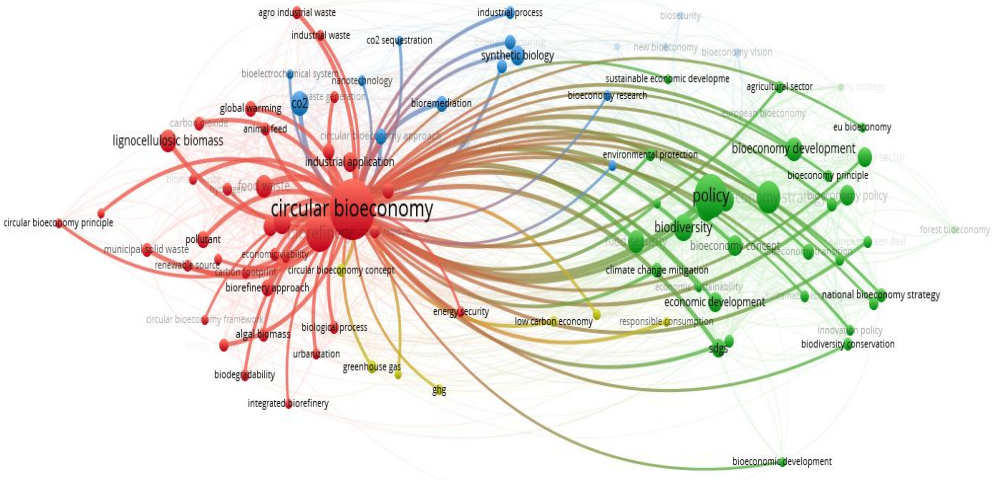

Figure 7*. Links of circular bioeconomy in the co-occurrence map of the most relevant terms. (data retrieved from VOSviewer).*

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The conceptual integration of circular economy and bioeconomy can be mainly related to core research and reflects scientific interests, as the policy documents and funding grants were not considered by the present research. Therefore, circular economy recurrence is not superficial, as the present research avoided the investigation of policy documents and grants, where the popularity oy of circular economy is undeniable.

The most influential researchers in the bioeconomy field, considered by the number of citations, are displayed in figure 8. The researchers are clustered in 7 groups, illustrated by distinct shades, with 137 co-authorship links.

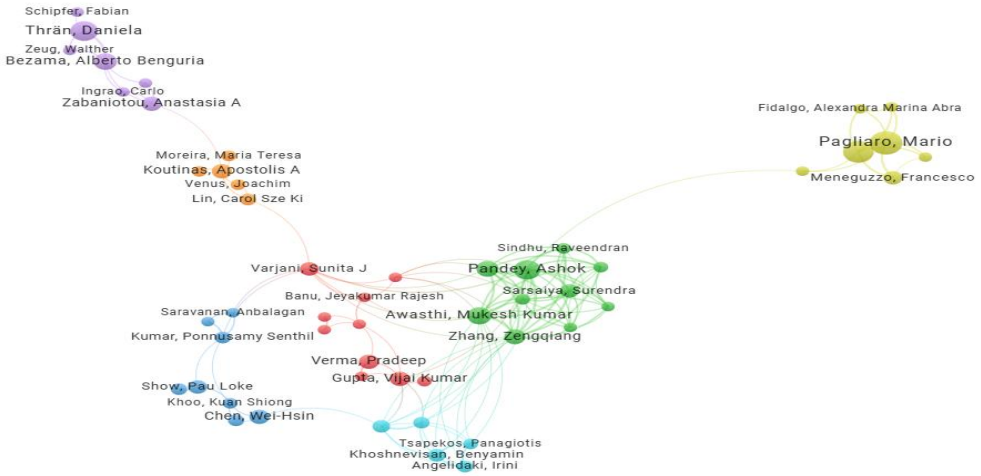

***Figure 8**. Topmost influential researchers in the field of bioeconomy (data retrieved from VOSviewer).*

The top 10 institutions with the most impact on bioeconomy field is displayed in table 3, pointing out the researchers list, based on the number of the citations. They are located all over the world, in India, China, Northern Europe, Malaysia and United States, offering views from both Global North and Global South. The top 10 sources of publication are shown in table 4, with Elsevier being the most influential publishing house in terms of bioeconomy.

Table 3: Top 10 most influential researchers in bioeconomy and their institutions, based on the number of citations

No.	Researcher	Institution, country	Citations
1	Ashok Pandey	Indian Institute of Toxicology Research, India	1,580
2	Mukesh Kumar Awasthi	North West Agriculture and Forestry University, China	1,481
3	Nils Droste	Lund University, Sweden	1,433
4	Pekka Leskinen	European Forest Institute, Finland	1,406
5	Marianne Thomsen	University of Copenhagen, Denmark	1,328
6	Mohammad Taherzadeh	University of Borås, Sweden	976
7	Anne Toppinen	University of Helsinki, Finland	872
8	Meisam Tabatabaei	University Malaysia Terengganu, Malaysia	856

9	Katja Lahtinen	Natural Resources Institute Finland, Finland	838
10	Jaana Korhonen	Oak Ridge Associated Universities, United States	796

processed from Dimensions.

Table 4: Top 10 most journals and their publishing houses, based on the number of publications

No.	Title	Number of publications	Publishing house
1	Sustainability	269	MDPI
2	Journal of Cleaner Production	186	Elsevier
3	Bioresource Technology	158	Elsevier
4	Forest Policy and Economics	79	Elsevier
5	Biofuels Bioproducts and Biorefining	76	Wiley
6	Renewable and Sustainable Energy Reviews	75	Elsevier
7	Energies	72	MDPI
8	New Biotechnology	67	Elsevier
9	The Science of the Total Environment	64	Elsevier
10	Journal of Environmental Management	58	Elsevier

processed from Dimensions.

By gathering the relevant information, the paper attempts to decode bioeconomy and identifies the key elements needed for a comprehensive yet concise definition of bioeconomy, as presented in table 5. The content analysis of the most cited papers revealed the main elements, which were grouped and briefly described into eight main clusters. Their significance was explained and further refined to identify the key issues needed for a comprehensive definition. The identified main elements show that bioeconomy stands at the convergence of many areas of interest, being an interdisciplinary field, with sustainable solutions across industries which promote equitable development, both in Global North and Global South.

Table 5: Key elements of a comprehensive bioeconomy definition derived from content analysis

Element	Description	Significance	Refined key issues
Knowledge-based	driven by research, innovation, and technology	distinguishes from traditional bio-based economies, fosters efficiency and new solutions based on smart technologies and digitalization	driven by technology
Sustainable resource management	production, utilization, conservation, and regeneration of renewable biological resources	ensures long-term availability, minimizes environmental impact, considers our planet's regenerative capacity	utilizes biological resources, biotechnologies, and bio-based innovations
Cross-sectoral application	applicable across all industries	enables broad transformation and addresses diverse societal needs	solutions across industries

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Commitment to sustainability	environmental, economic, and social dimensions	ensures complete benefits and responsible development	sustainable solutions across industries
Circular economy integration	maximizes resource efficiency, minimizes waste and promotes closed-loop systems	reduces environmental footprint and enhances economic viability	advancing circular economy principles
Industrial & agricultural applications	biofuels, bio-based chemicals, biomaterials	fosters complete, sustainable, and equitable solutions for sane economic growth, while reducing dependency on fossil fuels	replacing fossil-based materials with renewable materials
Equitable benefit sharing	prioritizes inclusivity and fair distribution of benefits	ensures social justice and broad stakeholder engagement	equitable development through resource efficiency, waste reduction, and climate-friendly production systems
Policy and regulations	standards, incentives, measurements, governance frameworks	fosters responsible innovation, supports fair market development, strengthens economies within the Earth regenerative capacity	responsible innovations within the Earth regenerative capacity

The proposed definition, based on the refinement of the eight key elements introduced above, is as follows. *Bioeconomy represents a technology-driven economic system that utilizes biological resources, biotechnologies, and bio-based responsible innovations to develop sustainable solutions across industries. It focuses on replacing fossil-based materials with renewable materials, advancing circular economy principles, and promoting equitable development through resource efficiency, waste reduction, and climate-friendly production systems within the Earth regenerative capacity*.

The definition brings new emphasis on responsible technical innovations and equitable development referring to the Earth regenerative capacity. In such a way it refers to cutting-edge technologies, but also to responsible innovations within the Earth regenerative capacity respecting biodiversity in both Global North and Global South. Bioeconomy was previously related to economic aspects, as value creation from biological resources (Leavy et al, 2024), or to environmental aspects, as ecological impact (Liobikiene & Miceikiene, 2023) or was correlated with specific fields, like food production (Trigo et al, 2023). The proposed definition does not limit the bioeconomy to one or several sectors but attempts to offer an integrative view where all the pillars of sustainable development are to be considered. However, the definition is perfectible, and further research could complement this research, especially in the field of policy innovations.

To be responsibly applied, bioeconomy must be based on policy frameworks and regulations which are meant to support fair market development but also need to be committed to sustainability all over the planet. By doing so, bioeconomy will foster environmental resilience and a regenerative future for everyone, also in the

underrepresented Global South, as many previous pathways followed the aims of Global North (Johnson et al, 2022).

The contributions of this study are important for revealing major literature streams in the field of bioeconomy. This research brings the first bibliometric research, to the knowledge of the author, that analyses the literature pathways of bioeconomy using Dimensions web interface (Digital Science, 2018) and attempts a comprehensive definition. However, there is a limitation correlated with the use of exclusive use of Dimensions, as it was considered the best at this time, employing a free, unbiased and friendly interface. Moreover, Dimensions platform has integrated VOSviewer, unlike other databases, like Scopus and Web of Science, which makes it easier to the interested researcher to preview co-authorship and co-citation networks. An additional limitation is correlated with the selection of the keywords, which reflects personal views, but included all the possible spellings in American and British English and covered all the publication during the considered interval. A constraint resulting from the applied software resides in a confined number of papers, as the keywords were present only in title and abstract, as otherwise, the selection would be much higher, impossible to be properly analyzed by VOSviewer. Nevertheless, the presence of the keywords in title and abstract ensures that the selected papers refer to bioeconomy, as otherwise the word frequency might be correlated within the text only to explanations or contrast or buzzwords. Moreover, to overcome this limitation of the software, the content analysis was performed for the most cited papers.

6. Conclusions

This research identifies the most important aspects of bioeconomy from recent literature, as intended by the research questions. The yearly scientific production and the citations by year significantly increased over the studied interval, with contributions from all the world, with India, China and Northern European countries (Sweden, Finland, and Denmark) leading the way. The literature streams from 2010 to 2024 show that the most influential editing house for bioeconomy is Elsevier, being a selection for the researchers interested in the field of bioeconomy (editing 7 journals out of 10, from top 10 journals). The key elements for a suitable definition of bioeconomy, as collected and synthesized from the literature streams, were identified and used to attempt a comprehensive definition.

The outcomes of this paper offer a better understanding of bioeconomy and allow the mapping of contemporary research interests and prepares the way for future research tracks, orienting interested researchers towards top authors, journals and institutions. The findings of this paper may be valuable for researchers, academia and policy makers interested in consolidating the bioeconomy model to render a system where bioeconomy can be understood, defined and properly measured.

This research will be followed by the systematic review of the papers with the most citations in the area of bioeconomy which were collected during this analysis, with a focus on circular economy.

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