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Review on research trends in biomass resources and biofuel potential: a bibliometric analysis

Kwaku ANTWI[1]

[1]Akenten Appiah Menka University of Skills Training and Entrepreneurial Development, Kumasi, Ghana.
*E-mail: kantwi@aamusted.edu.gh

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ABSTRACT: This review aims to analyze and synthesize the existing body of literature on biomass resources and their potential for biofuel production. By employing bibliometric methods, this study seeks to identify the key research trends, gaps, and emerging areas of interest in this field. A total of 194 documents deemed appropriate for the study on biomass resources and biofuel potential over the past four decades, i.e., 1980 and 2022 were reviewed. The analysis was done with the VOSviewer software (version 1.6.13). The analysis focused on the bibliographic coupling of countries, sources, co-authorship of authors, citation of documents, and co-occurrence of keywords, which were presented as network visualization maps. The findings revealed that research on biomass resources and biofuel potential is multidisciplinary in character and developing quickly, encompassing nations from around the world. It is evident that Africa lags in this area of research. Therefore, it is recommended that researchers on the continent focus more on this research domain to help address the gap in this research area. This will help researchers and other stakeholders in the energy sector to become familiar with the current and cutting-edge technologies that could promote effective and efficient biomass resources and biofuel potential.
Keywords: biomass; biofuel; agricultural waste; network visualization maps; VOSviewer.

Tendências de pesquisa em recursos de biomassa e potencial de biocombustíveis: uma análise bibliométrica

RESUMO: Esta revisão visa analisar e sintetizar o corpo de literatura existente sobre recursos de biomassa e seu potencial para a produção de biocombustíveis. Ao empregar métodos bibliométricos, este estudo procura identificar as principais tendências de pesquisa, lacunas e áreas emergentes de interesse neste campo. Foram revisados 194 documentos considerados adequados para o estudo dos recursos de biomassa e do potencial de biocombustíveis nas últimas quatro décadas, ou seja, 1980 e 2022. A análise foi feita com o software VOSviewer (versão 1.6.13). A análise centrou-se no acoplamento bibliográfico de países, fontes, coautoria de autores, citação de documentos e coocorrência de palavras-chave, que foram apresentados como mapas de visualização em rede. Os resultados revelaram que a pesquisa sobre recursos de biomassa e potencial de biocombustíveis é de caráter multidisciplinar e está se desenvolvendo rapidamente, abrangendo nações de todo o mundo. É evidente que a África está atrasada nesta área de pesquisa. Portanto, recomenda-se que os pesquisadores do continente se concentrem mais neste domínio de pesquisa para ajudar a preencher a lacuna nesta área de pesquisa. Isso ajudará os pesquisadores e outras partes interessadas no setor de energia a se familiarizarem com as tecnologias atuais e de ponta que podem promover recursos de biomassa eficazes e eficientes e o potencial de biocombustíveis.
Palavras-chaves: biomassa; biocombustível; resíduos agrícolas; mapas de visualização de rede; VOSviewer.

1. INTRODUCTION

Biomass resources and biofuels have emerged as promising alternatives to traditional fossil fuels, offering the potential for sustainable and renewable energy production (MAROA et al., 2021; HASAN et al., 2023). Over the past few decades, extensive research has been conducted worldwide to explore and exploit the diverse biomass resources available and their viability for biofuel production. A bibliometric review provides a systematic approach to analyzing and assessing the existing body of literature, enabling a comprehensive understanding of the research trends, knowledge gaps, and emerging areas of interest in this field.

The bibliometric analysis involves quantitatively evaluating scientific publications, patents, and conference proceedings, using various indicators such as citations, co-citations, and co-authorship patterns (HU et al., 2021). By employing these methods, researchers can identify influential research works, prominent authors, and collaborations within a specific research domain. In the context of biomass resources and biofuels, a bibliometric review can offer valuable insights into the development and evolution of this field, aiding researchers, policymakers, and industry stakeholders in making informed decisions.

This bibliometric review aims to provide a comprehensive analysis of the research trends in biomass

resources and their potential for biofuel production. By examining a wide range of scholarly articles, conference papers, and patents, this study seeks to identify the key themes, research clusters, and influential publications that have shaped the trajectory of this field. In doing so, it will shed light on the major areas of focus, research gaps, and emerging research directions.

Furthermore, the review will employ citation analysis to determine the most influential articles and authors in the field of biomass resources and biofuels. By identifying the highly cited works, this study will highlight the foundational research and pivotal contributions that have influenced subsequent investigations. Additionally, co-citation analysis will be utilized to map the intellectual structure of the field, identifying clusters of closely related research areas and the interconnections between different research groups.

The findings of this bibliometric review will serve as a valuable resource for researchers, policymakers, and industry professionals interested in biomass resources and biofuel potential. Providing an overview of the existing research landscape will enable stakeholders to identify current research trends, knowledge gaps, and areas that require further investigation. Ultimately, this review aims to contribute to developing sustainable and efficient biofuel technologies by providing a comprehensive understanding of the research trends and potential avenues for future exploration.

Although studies on biofuel and biomass resources in general abound, there is not yet enough evidence of studies identifying the research trends in biomass resources and biofuel potential. Evidence of bibliometric reviews in this area of study is lacking. This paper presents a bibliometric review of biomass resources and biofuel potential, specifically focusing on reviewing the potential for biofuel production and the availability of biomass resources. The review will encompass a comprehensive analysis of scientific articles, conference papers, and patents published within a specified timeframe. By mapping the knowledge landscape through bibliometric indicators such as citation analysis, co-citation analysis, and co-authorship analysis, this study intends to provide a holistic understanding of the research trajectory and collaborations within the biomass and biofuel domain. The findings of this review will contribute to groups, and significant research themes, ultimately aiding researchers, policymakers, and industry stakeholders in making informed decisions regarding biomass resource utilization and the development of sustainable biofuel technologies.

2. RESEARCH METHODOLOGY

The author selected the Scopus database as the data source for this study. Hosseini et al. (2018) believe that the Scopus database has a wide coverage of publications from diverse areas. Moreover, scientific research database such as Scopus provides researchers with information on the most important academic literature in any scientific domain (CHADEGANI et al., 2013). This makes Scopus a credible/trustworthy database. This study focused specifically on biomass resources and biofuel potential. Consequently, the specific keywords used for the search were: "biomass resources" "biofuel" "wood" and "agricultural waste". The search was limited to documents published over the past four decades, i.e., 1980 and 2022. This helped to clearly demonstrate how research on biomass resources and biofuel potential has evolved over time. The first search resulted in a total of 519 documents. The search was further refined to include only Articles, Conference Papers, and Book Chapters published in the subject areas of biomass resources, biofuel, wood, and agricultural waste. This resulted in a reduction from 519 to 439 documents. The search was further limited to only documents published in English resulting in a reduction from 439 to 384 documents.

The second stage was the screening; the titles and abstracts of the 384 documents were further screened to eliminate papers that did not align with the research title or theme. This was done by analyzing the content of the titles and abstracts. After the screening, a total of 194 documents were deemed appropriate for the study. The filtering and screening of the titles and abstracts were done on 10th March 2023.

A bibliometric review was then conducted in the third stage to analyze the 194 documents obtained in the second stage. The bibliometric review was done with the VOSviewer software (version 1.6.13). Bibliometric review is a quantitative technique involving the visual and logical analysis of articles by assessing, mapping, and identifying structural patterns in a research domain using mathematical models, visualization clusters, and algorithms (OLAWUMI; CHAN, 2018). Van Eck; Waltman (2014) clarified that the VOSviewer software, a bibliometric analysis tool, can help to display large visualization networks such that it becomes easily interpretable. Therefore, for this study, data was imported from the Scopus database unto the VOSviewer software to create network and overlay visualization maps.

Four visualization maps are presented in this study. The visualization maps used for the study are the bibliographic coupling of countries and sources, citation of documents and authors, and co-occurrence of keywords. The network visualization map represents items by their labels in a circle. Three factors – size, color, and link – influence the analysis of the network visualization map (VAN ECK; WALTMAN, 2019). First, the size of the label and the size of the circle of an item has a relation to the weight of the item; thus, bigger labels/circles represent higher weight. Secondly, all related items in a cluster network are presented in the same color. Finally, items are linked with lines; thus, the distance between two items indicates their relatedness. For example, the closer two items are to each other, the stronger their relatedness (VAN ECK; WALTMAN, 2019). Figure 1 shows the steps/stages adopted in this study.

3. RESULTS

3.1. Annual publication distribution

The number of publications from 1980 to 2022 is demonstrated in Figure 2. It is evident that very low or no publication was recorded from 1980 up to 2007. The highest increase was recorded in 2014, i.e., from 14 in 2013 to 19 in 2014. This is probably due to the conferences organized that had a specific focus on biomass resources and Biofuel potentials. However, the numbers declined from 19 in 2014 to 11 in 2015. The number of publications rose again from 11 in 2015 to 12 and 14 in 2016 and 2017. There was a dip in 2018 whilst a gradual increase was recorded from 2019 and a decline in 2020. A drop was recorded in 2021 and 2022 possibly due to delays in publications. Although the trend has not been smooth, the general trend of publications has been upward between 2008 to 2020.

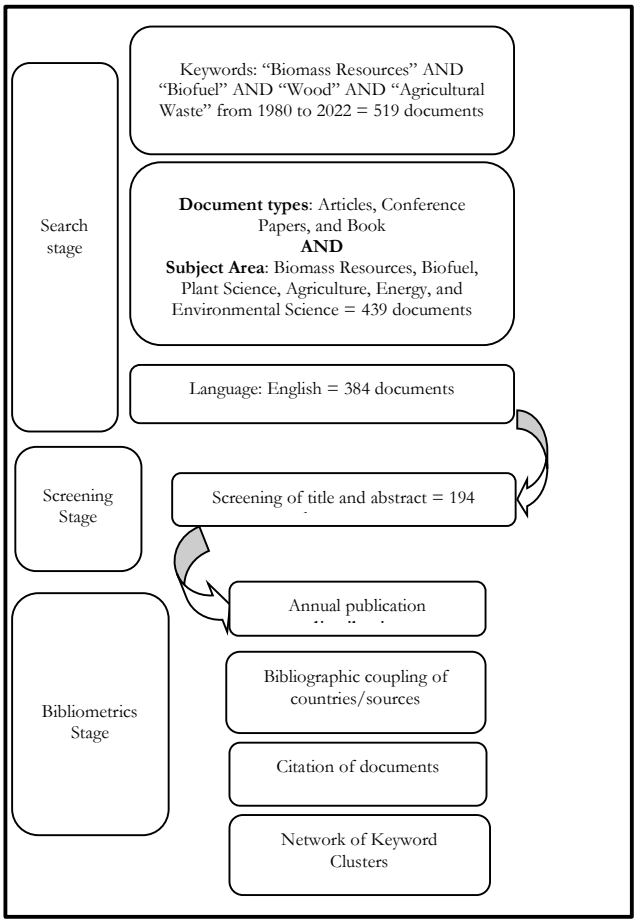

Figure 1. Steps followed in the methodology.
Figura 1. Etapas usadas na análise bibliométrica.

3.2. Bibliographic coupling of countries

A bibliographic coupling analysis of countries was done to first determine the number of publications recorded by each country, and secondly to evaluate the level of collaboration between/among the countries. The minimum number of documents of a country was set at 5 whilst the minimum number of citations of a country was set at 10. Out of the 56 countries, only 18 met this threshold. For each of the 18 countries, the total strength of the bibliographic coupling links with other countries was calculated. The countries with the greatest total link strength were selected. The United States had the highest number of documents, i.e., 43 with 4084 citations whereas the Russian Federation recorded the lowest number of citations, i.e., 30, with only 5 documents. Similar to Australia, France recorded a remarkable 769 citations with 5 documents. India, Sweden, China, Finland, and Germany recorded the second-highest number of documents. It is worth noting that no country in Africa met the threshold of 5 documents and 10 citations. This demonstrates that Africa lags in this area of research.

Table 1. Bibliographic coupling of countries.
Tabela 1. Produção bibliográfica por países.

No.	Country	Documents	Citations	Total link strength
1	United States	43	4084	1131
2	India	20	896	708
3	Brazil	9	540	608
4	Finland	10	355	585
5	Switzerland	8	142	450
6	Spain	9	244	435
7	Sweden	13	431	403
8	Germany	10	361	402
9	Italy	8	160	347
10	Norway	6	194	329
11	United Kingdom	6	287	266
12	Australia	5	722	233
13	Canada	5	240	228
14	France	5	769	165
15	China	11	372	129
16	Russian Federation	5	30	71
17	Japan	5	241	27
18	Latvia	6	36	5

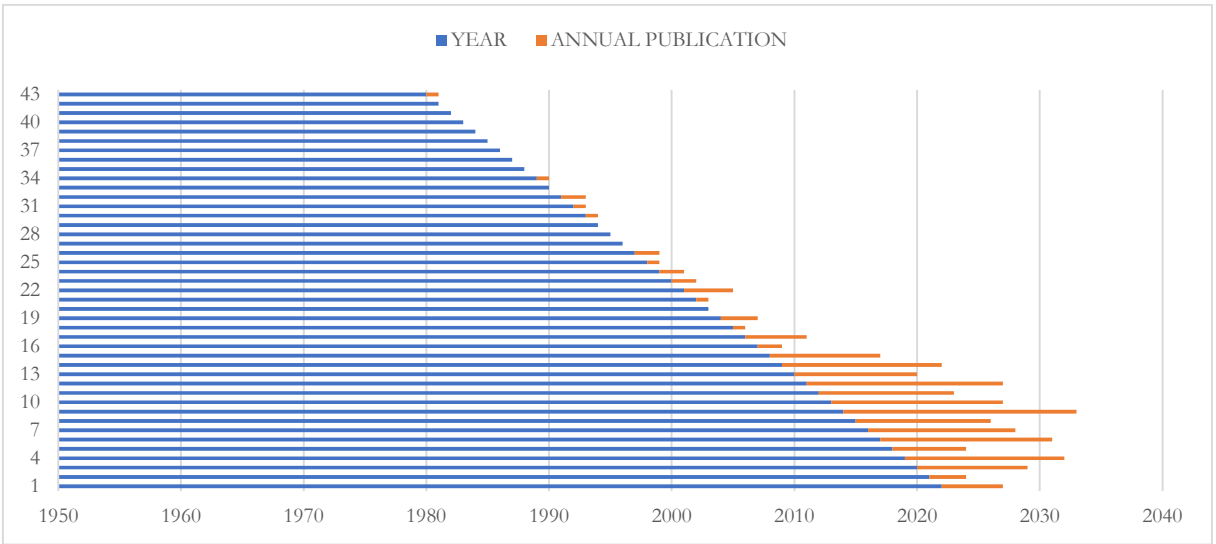

Figure 2. Annual publication research trend.
Figura 2. Tendência anual de pesquisa de publicações.

Regarding the link among the countries, the United States had the strongest link whilst Latvia had the weakest link. However, all countries had links with each other demonstrating a satisfactory level of research links among the countries. The network visualization map also reveals 5 clusters: cluster 1 had 6 items (Brazil, Canada, Latvia,

Norway, Sweden, and the United Kingdom); Cluster 2 had 4 items (China, Japan, Spain, and the United States); Cluster 3 had 3 items (India, Italy, and Russian Federation), Cluster 4 also had 3 items (Finland, Germany, and Switzerland) and cluster 5 had 2 items (Australia and France) (see Figure 3).

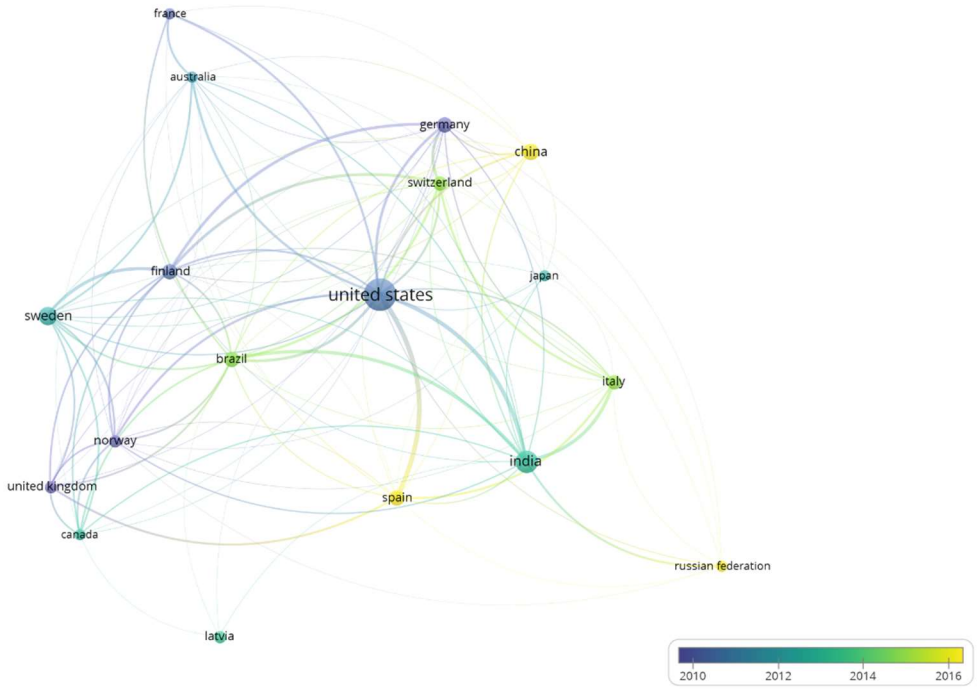

Figure 3. Country Network Visualization Map. Source: VOSviewer.
Figura 3. Mapa de visualização da rede do país. Fonte: VOSviewer.

3.3. Bibliographic coupling of sources

According to the bibliographic records, a total of 124 sources had publications in this area of study. Using the VOSviewer software, a minimum number of documents was set at 2 and the minimum citations were set at 5. Out of the total of 124 sources, only 26 met this threshold. For each of the 26 sources, the total strength of the bibliographic coupling links with other sources was calculated. The sources with the greatest total link strength were selected. These, without a doubt, are the sources that have contributed to this area of research. It is quite revealing that all these 26 sources have either an element of biomass resources or biofuel in the title. Table 2 further reveals that *Biomass* and *Bioenergy* had the highest number of documents followed by *Engineering for Rural Development* and *Bioresource Technology*. However, regarding citations, *Science* was far ahead of all the journals followed by *Biomass and Bioenergy*. This is anticipated because technology in *Biomass resources* and *Biofuel* potential is the focus of *Biomass* and *Biofuel*. Thus, it could be argued that *Engineering for Rural Development, Bioresource Technology, and Biomass* and *Bioenergy* are the sources that have had the greatest impact in this area of research. *Applied Microbiology* and *Biotechnology* had the highest Total link strength followed by *Biotechnology for Biofuel*. Apart from *Nature, Energy for Sustainable Development, Applied Biochemistry and Biotechnology, and Nongye Gongcheng Xuebao/Transaction* which had the weakest total link strength, it appears all the other sources have a good link (see Figure 4).

3.4. Citation of documents

A citation analysis of documents was done to determine the level of citations of the specific documents. The minimum number of citations of a document was set at 30. Out of the 194 documents, 59 met the threshold generating 48 items with 8 clusters. Cluster 1 was made up of 10 documents, Cluster 2 had 7 documents. Cluster 3 had 6 documents and Cluster 4 had 5 documents whereas clusters 5, 6, and 7 had 4 documents, and cluster 8 was made up of 3 documents. It is worth mentioning that the focus of all eight clusters was "biomass resources and biofuel potential". A review of the remaining clusters' topics reveals a similar trend of research. However, other trends noticeable in the topics are biofuel production potential; woody biomass as renewable energy; biomass residue availability and bioenergy yields; production of bio-energy from wood biomass; and the potential contribution of biomass to sustainable energy development. Of the 59 documents that met the threshold, only six authors collaborated in their research work as clearly shown in Figure 5a. That is Ragauskas A.J. 2006 collaborated with Puy 2011, on the topic: of from wood to fuels. Puy 2011 collaborated with Zhu J.Y 2010 on the topic: pretreatment of woody biomass for biofuel production: energy efficiency, technologies, and recalcitrance. Also, Puy 2011, collaborated with Nieminen K 2012 and Normark M. 2014 on the challenges of the utilization of wood polymers: how can they be overcome?

Again, Puy 2011, collaborated with Nieminen K and Sanders K. on the topic: of optimizing wood development in bioenergy trees. Finally, Normark M. 2014 collaborated with Puy 2011 on the topic: analysis, pretreatment, and enzymatic saccharification of different fractions of scot pine. It can be inferred from the analysis of the documents that there is less collaboration between/among authors as shown in Figure 5b.

Table 2. Top 26 journals (sources) with number of documents, citations, and total link strength (TLS).
Tabela 2. Top 26 periódicos (fontes) com número de documentos, citações e força total do link.

No	Country	Documents	Citations	TLS
1	Applied Microbiology and Biotechnology	5	509	81
2	Biotechnology for Biofuels	4	230	36
3	Biomass and Bioenergy	17	1215	32
4	Biotechnology Advances	4	453	28
5	Biofuels, Bioproducts, and Biorefining	2	117	24
6	Bioresource Technology	6	709	23
7	Industrial Crops and Products	3	93	21
8	GCB Bioenergy	3	44	19
9	Renewable and Sustainable Energy Resources	3	231	15
10	Sustainability (Switzerland)	2	151	15
11	Energy Conversion and Management	3	516	13
12	Science	2	1503	11
13	Int. Journal of Life Cycle Ass.	2	126	9
14	Renewable Energy	3	176	9
15	Plos One	2	74	8
16	Energy	4	115	6
17	Energy Policy	3	176	6
18	Engineering for Rural Development	7	25	5
19	Green Energy and Technology	3	11	4
20	Resource Conservation and Recycling	2	155	3
21	Applied Energy	2	41	1
22	Environmental Engineering and Management	2	14	1
23	Applied Biochemistry and Biotechnology	2	21	0
24	Energy for Sustainable Development	2	50	0
25	Nature	4	360	0
26	Nongye Gongcheng Xuebao/Transaction	2	13	0

3.5. Network of keyword clusters

A keyword co-occurrence analysis was conducted to determine the trends and evolution of biomass resources and biofuel. Hu et al. (2018) revealed that clustering analysis helps to identify patterns by grouping sources that share similar words and attribute values. The scope of any research study is determined by the keywords. A network of keyword clusters was derived from a total of 2739 keywords. A minimum number of 10 co-occurrence of keywords was set and 74 keywords co-occurred generating 4 clusters. To ensure that only relevant keywords were captured in the network, some words such as non-human, costs, United States, and electricity were taken out of the analysis.

Four clusters emerged from the analysis. Cluster 1 had 26 keywords; some of the keywords related to biomass resources and biofuel in this cluster are lignocellulosic biomass, bioenergy, and biofuel. Cluster 2 had 24 keywords; notable keywords in this cluster are biofuel production, biorefinery, biotechnology, wood, and gasification. Cluster 3 had 14 keywords; some of the noticeable keywords in this cluster are biomass, biological materials, fuels, and renewable energy resources. Cluster 4 had 10 keywords including biofuel, biogas, biomass power, plant residue, and alternative energy. To allow for an informed discussion, the clusters are presented in different colors to demonstrate the timeframe where such words dominated (see the overlay visualization map in Figure 6).

3.6. Co-occurrences of authors

A co-occurrence analysis of authors was done to determine the level of authors' work co-occurred. The minimum number of documents of an author was set at 10. Out of the 679 authors, 22 met the thresholds generating 5 Clusters. For each of the 22 authors, the total strength of the co-authorship links with other authors was calculated. The authors with the greatest link strength were calculated.

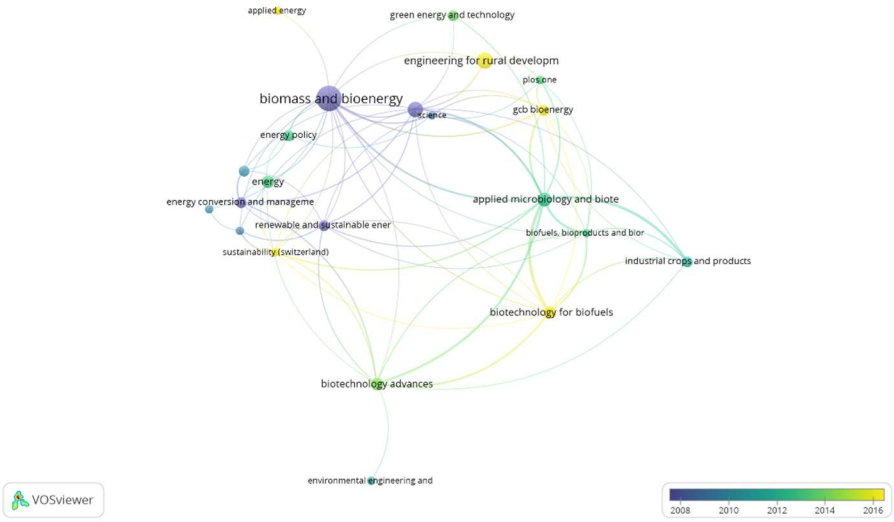

Figure 4. Sources network visualization map.
Figura 4. Mapa de visualização de rede de fontes.

Figure 5a. Documents citation network visualization map.
Figura 5a. Mapa de visualização de rede de citação de documentos.

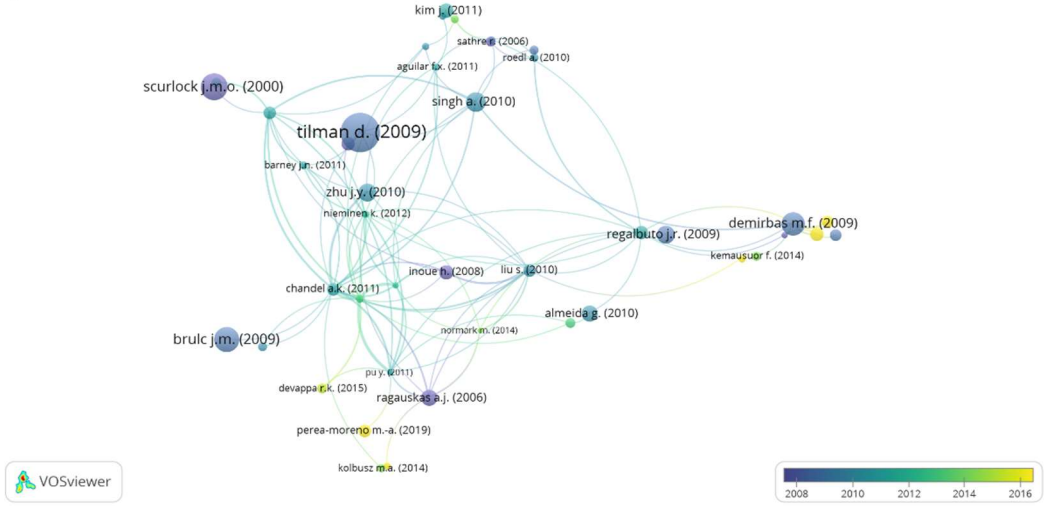

Figure 5b. Documents citation network visualization map.
Figura 5b. Mapa de visualização de rede de citação de documentos.

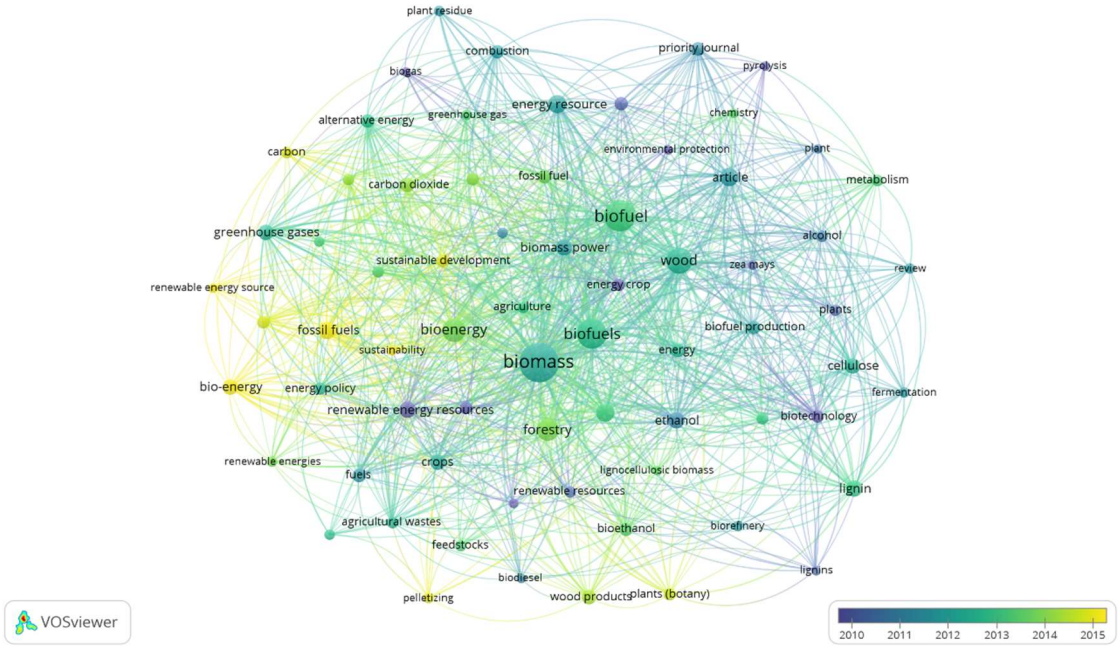

Figure 6. Overlay Visualization Map of Co-occurring Keywords.
Figura 6. Mapa de visualização de sobreposição de palavras-chave coocorrentes.

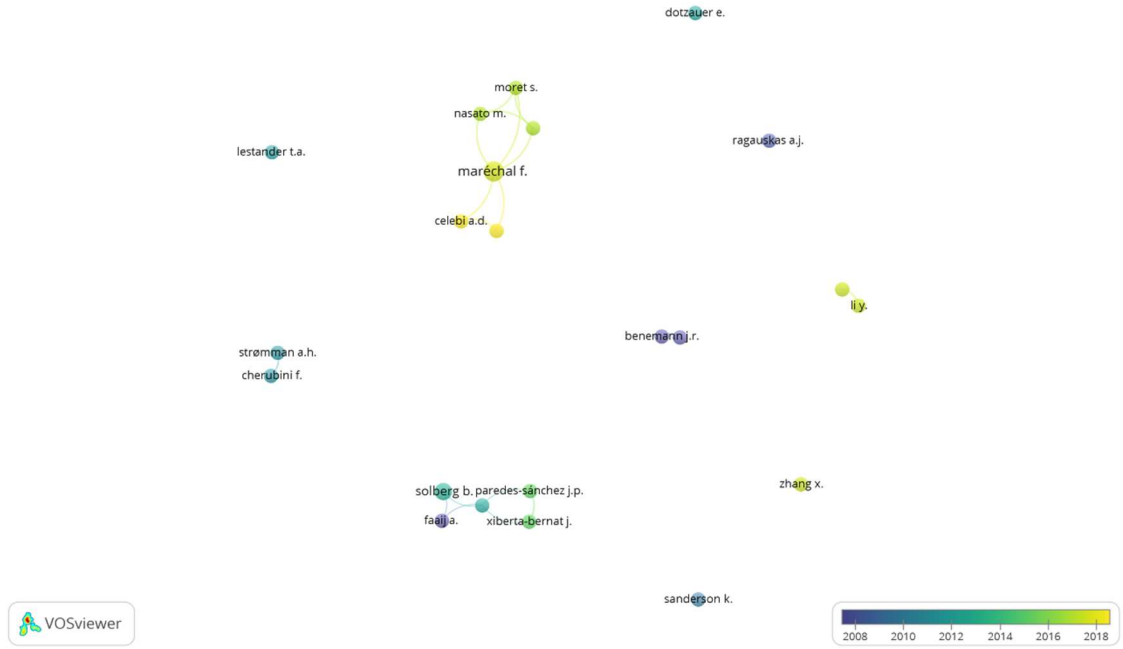

Figure 7. Overlay visualization map of co-occurrence of authors. Source:
Figura 7. Mapa de visualização da sobreposição da coocorrência dos autores.

4. DISCUSSION

Because they are plentiful, renewable, and sustainable, biomass resources are seen as a possible alternative to fossil fuels. The last ten years have seen an increase in the usage of biomass resources as an energy source as a result of growing environmental concerns and the depletion of fossil fuel stocks. Biofuel production is a promising method for turning biomass resources into energy since it is considered more environmentally friendly than other fuel production methods. The goal of the current bibliometric evaluation is to give readers a broad overview of current research directions in biomass resources and biofuel potential.

Utilizing the Scopus database, which retrieved about 520 papers with a focus on biomass resources and biofuel potential and written between 1980 and 2022, the bibliometric review was carried out. The study on biomass resources and biofuel potential has risen tremendously in the previous 10 years, with an annual growth rate of about 9%, according to the bibliometric analysis of these papers. Most of the pieces came from China, the United States, and Europe. The findings also revealed a lack of research productivity in nations with abundant biomass resources, such as Brazil, India, and Africa.

Characterizing biomass feedstocks in order to comprehend their make-up and potential for usage has been a major focus in the field of biomass resources and biofuel potential. By using this knowledge, the conversion process may be improved, the best feedstocks can be chosen, and the entire supply chain's effectiveness can be increased.

Recent years have seen a rise in the utilization of biomass resources for biofuels, partly due to growing environmental concerns over conventional fossil fuels.

Research in various disciplines, including environmental science, chemical engineering, material science, and biochemistry, was conducted on the potential for biomass resources and biofuels. The principal research area was biomass conversion technologies, emphasizing creating effective and affordable conversion pathways using thermal, biochemical, and thermochemical processes. Although not uniformly graded, it is clear that since 2008, the overall trend in publications on biomass resources and biofuel potential has been higher.

The bibliometric review reveals that the research in biomass resources and biofuel potential is growing rapidly and is multidisciplinary in nature. As demand for alternative fuels grows and awareness of environmental impacts increases, research in this field will continue to be essential in the future as reported by VELVIZHI et al. (2022).

5. CONCLUSIONS

Overall, the bibliometric analysis shows that research on biomass resources and biofuel potential is multidisciplinary in character, developing quickly. This study remains crucial as the demand for alternative fuels rises and public awareness of their effects on the environment rises.

The bibliometric analysis of research trends in biomass resources and potential for biofuels demonstrates that this topic has expanded dramatically during the past 10 years. The research has been diverse, encompassing numerous academic disciplines and nations worldwide.

This trend provides a direction to guide future investigation in this area of research. The representation of publications presented in this study is somewhat limited since the data set used for the analysis was limited to the Scopus database. Also, only documents published in English were considered, excluding other possibly relevant documents published in other languages. Therefore, the study recommends that further studies be conducted using more than one database. Moreover, it is evident that African lags in this area of research. It is, therefore, highly recommended that researchers on the continent focus more attention on this research domain to help address the gap in this research area.

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Availability of data: Data for this study has been added as an attachment. But the raw data and analyzed data can be obtained by request to corresponding Author by e-mail.

Conflict of Interest: The author declares that there are no conflicts of interest with other researchers or institutions.