Journal of Environmental Management 336 (2023) 117644

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

Sustainable biofuel economy: A mapping through bibliometric research

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ARTICLE INFO

Handling Editor: Raf Dewil

Keywords:
Sustainable biofuel economy
Renewable energy
Sustainable development goals
Bibliometrics analysis
Bioeconomy

ABSTRACT

Biofuels have received a lot of attention as an important source of renewable energy, with number of economic impacts. This study aims to investigate the economic potential of biofuels and then extract core aspects of how biofuels relate to a sustainable economy in order to achieve a sustainable biofuel economy. This study conducts a bibliometric analysis of publications about biofuel economic research covering 2001 to 2022 experimenting with multiple bibliometric tools, such as R Studio, Biblioshiny, and VOSviewer. Findings show that research on biofuels and biofuel production growth are positively correlated. From the analyzed publications, The United States, India, China, and Europe are the largest biofuel markets, with the USA taking the lead in publishing scientific papers, engaging country collaboration on biofuel, and has the highest social impact. Findings also show that the United Kingdom, the Netherlands, Germany, France, Sweden, and Spain are more inclined to develop sustainable biofuel economies and energy than other European countries. It also indicates that sustainable biofuel economies are still far behind those of less developed and developing countries. Besides, this study finds that biofuel linked to sustainable economy with poverty reduction, agriculture development, renewable energy production, economic growth, climate change policy, environmental protection, carbon emission reduction, green-house gas emission, land use policy, technological innovations, and development. The findings of this bibliometric research are presented using different clusters, mapping, and statistics. The discussion of this study affirms the good and effective policies for a sustainable biofuel economy.

1. Introduction

In recent years, the increasing international energy demand and soaring oil prices have forced energy-consuming countries to turn their attention to alternative energy sources, especially the development of biofuels (Cabrera-Jiménez et al., 2022). Liquid biofuel production and consumption help combat climate change and promote agricultural diversity, energy security, and rural development (Nakamya, 2022). The rapid expansion of biofuel production and consumption continuously influences the diversified field of a sustainable economy, ultimately leading to sustainable developments through maximising social, economic, and environmental benefits (Correa et al., 2019). Considering the concept of a sustainable biofuel economy, biofuel has significant economic, social, and environmental benefits (Amigun et al., 2011; Correa et al., 2019). Recent advancements in biofuels production are evident in numerous social and environmental benefits, but its economic viability is highly dependent on feedstock availability, technology options, project design, project management, and production capacities (Lal et al., 2022; Pasha et al., 2021; Sheth et al., 2021).

Some studies focus on concepts of biofuel economy directly related to sustainable development goals (SDGs). For example, the use of biofuels offers new opportunities for poverty alleviation and economic growth for agriculture-based economies in low-income countries (Costa and Oliveira, 2022; Prasad and Ingle, 2019; Vera et al., 2022). Hartley

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https://doi.org/10.1016/j.jenvman.2023.117644
Received 20 November 2022; Received in revised form 7 February 2023; Accepted 28 February 2023
Available online 7 March 2023

et al. (2019) mentioned that the development of the biofuel value chain positively boosts economic growth and increases employment opportunities, enables efficient labour markets, and allows labour mobility. Several other studies also reported that it increases socioeconomic well-being by expanding the agricultural market and raising household income (Datta, 2022; Portale, 2012; Yimam, 2022).

Besides, while reviewing the economic effect of biofuel, we find that the biofuel sector has a significant contribution to the national economy. It is mostly beneficiary for farmers and agro-businessmen due to its growing production of energy crops and by creating some other opportunities. Farmers are the primary beneficiaries of biofuels compared to others because they are the producers of the feedstocks used to make biofuels, e.g., sugarcane, corn, and soybeans (Shahid et al., 2021). Farmers sell their crops to biofuel manufacturers as raw materials for producing biofuels (bioethanol and biodiesel), earning new incomes for themselves (Ambaye et al., 2021a; Shahid et al., 2021). Biofuel production utilises some unused agricultural lands that are not suitable for producing food crops. As a result of producing biofuels, farmers can become more financially stable, more profitable, and less dependent on traditional markets (Alazaiza et al., 2022; Rathmann et al., 2010). These opportunities provide them with a new market for their crops, which can lead to increased revenue and improved economic stability. Biofuels can also create jobs in rural areas, benefiting farmers and their communities (Coyle, 2007; Hannon et al., 2010; Tudge et al., 2021). According to the report published by The Economic Impact of Biodiesel (2022), US biofuel production reduces the dependency of the entire country on foreign energy. This report shows that the biofuel and renewable diesel sector created a massive scope of employment (65,000 jobs), economic impacts ($17 billion), and economic opportunity ($780 million) in 2021. The hiring of new employees by biodiesel companies is increasing because of their stable growth compared to the standard of renewable fuel production.[1] Ambaye et al. (2021b) also provided evidence that biofuel production with high emerging technology reduces fossil fuel dependency.

Some studies (Igbokwe et al., 2022; Liu et al., 2023; Oliveira et al., 2022) focus on the biofuel economy regarding biofuel prospects, implementation challenges, production systems, transportation issues, promoting sustainable circular bioeconomy and more. Despite many studies on biofuels, there is no convincing review evidence focusing specifically on biofuels and sustainable economic development, given the promise of the SDGs. We consider this lack of specific research on sustainable biofuel economies a research gap. To fill such a backdrop, we review existing literature to answer the two primary research questions in the following sections. The first question is *'What aspects are biofuel connected to the economy?"* and the second question is *"How does the biofuel economy attach to sustainable development, particularly United Nations' Sustainable Development Goals (SDGs)?"*. To address the stated questions, different quantitative findings from the bibliometric analysis are experimented in this study. Particularly quantitative findings are annual scientific production, country-specific collaboration, countries with strong influence on this study area, most popular sources, most significant scientific contributions, thematic map, thematic evaluation, co-occurrence analysis, and conceptual structure map. In most cases, this study follows the contents of bibliometric analysis from the following literature (Assis and Gonçalves, 2022; Bouteska et al., 2023; Chai et al., 2022; Hasan et al., 2019; Concari et al., 2022; Ding et al., 2022; Donthu et al., 2021; Firdaus et al., 2019; Ilmasari et al., 2022; Linnenluecke et al., 2016; Purba et al., 2022; Saini et al., 2022; Tan et al., 2021; Usman and Ho, 2020; Zhang et al., 2022).

For the first question, though few studies focus on the impact of biofuel on economic growth (GDP growth), except for this aspect, no other studies focus on how and what other aspects biofuel connects to the economy and SDGs. The second question is entirely new; to the best of our knowledge, this study is the first that addresses this research gap.

The primary aim of this study is specified, complying with the above backgrounds. The primary objective is to identify the components of a sustainable biofuel economy, particularly in what aspects biofuel influences economic sustainability. Apart from this, this study also aims to identify the development patterns and prospective of a sustainable biofuel economy, which includes the publication trend of the biofuel economy, exploring the country-specific research publications and collaborations, countries with the highest research impact, the co-occurrence relationship between the keywords, and the conceptual structure map of sustainable biofuel economy.

This study also has significant implications for the literature on biofuels' socio-economic and environmental aspects. The findings have implications for sustainable biofuel economic policy, challenges, and potential. In addition, this study has a meaningful impact on the stockholders concerning the sustainable use of environmental resources. The study outlines as follows: Section 2 introduces the methodology, which includes data collection, analysis, and visualisation methods as well as a methodological framework; Section 3 describes the biofuel economy results, including country scientific production and collaboration, globally cited countries and documents, co-occurrence assessment, and a biofuel thematic map; Section 4 describes the biofuel economy thematic discussions, and policy recommendation; and Section 5 summarises the conclusion, limitations, and avenues for future research.

2. Methodology

2.1. Data collection

This study mainly follows the research method of bibliometrics to solve the research problem. For the specific research question of this study, quantitative analysis using existing bibliometric data is more appropriate. The methodological route is not suitable for meta-analyses because meta-analyses use existing empirical results for summarising new findings. Therefore, this study follows the following bibliometric methodological process. The experiment dataset comes from Scopus's abstract and citation database (http://www.scopus.com). This database is the most common and well-known data source for bibliometric studies. Also, Scopus is easily accessible across most universities' online library systems (Linnenluecke et al., 2020). We specify the search criteria by focusing on biofuel literature published in the journal in business, management, accounting, economics, econometrics, and finance domains. This study does not search for extended keywords as our research solely focuses on the 'biofuel' OR 'biodiesel' OR 'bio ethanol' titles published in the related journals and specified domains. After searching with the title, we find 47,983 articles from Scopus. After limiting the research area to *Economics, Econometrics and Finance* (EEF) and *Business, Management and Accounting* (BMA), we find 907 in EEF journals and 1165 in BMA journals in the Scopus database (A total of 1856). After limiting ourselves only to English, we finally found 1783 published articles from Scopus. However, limiting to till 2022, finally, we get 1767 titles for the final analysis.

2.2. Data analysis

This study merges all documents into a single source file having bibliometric data from the data sources. Following the seminal work of Aria and Cuccurullo (2017), this study applies R Studio version 3.0.1 in data mapping and Biblioshiny for modeling. We extract the BibTex file from Scopus. After collecting both data, we converted those to an excel sheet using *Biblioshiny* and merged both datasets using the command in R Studio. The programming code and packages are presented in the appendix section. This study applies multiple analysis methods to bibliometric data to explore the global biofuel economy and sustainability

[1] https://www.regi.com/blogs/blog-details/resource-library/2019/02/15/the-economic-impact-of-biodiesel.

status. After extracting the complete information from the Scopus database, we mainly use publication types, authors, article titles, source titles, author keywords, keywords plus, abstracts, and affiliations. Also, the references, cited reference count, times cited, WoS core times cited, publisher, journal abbreviation, and publication year data for the bibliometric analysis are used to explore the sustainable biofuel economy.

2.3. Data visualisation

Most bibliometrics research uses multiple software such as Gephi, Leximancer, and VOSviewer to visualise the data (Donthu et al., 2021). This study also uses two different software (the *Bibliometrics* package in R Studio and VOSviewer to visualise the analysis. This study performs most visualisations with the *Bibliometrix* package in R Studio (Aria and Cuccurullo, 2017), a command-based software. Another software is VOSviewer (Perianes-Rodriguez et al., 2016, van Eck and Waltman, 2010; Waltman et al., 2010), a graphical user interface-based software.

2.4. Methodological framework

Several figures and tables exhibit the findings in most cases. We also use the tree maps and interpret them based on the most highlighted and top issues. For example, we explain top sources, countries, top-cited papers, etc. This study follows a structured methodological framework of the bibliometric study done by (Donthu et al., 2021). Fig. 1 presents the methodological framework in the following sections.

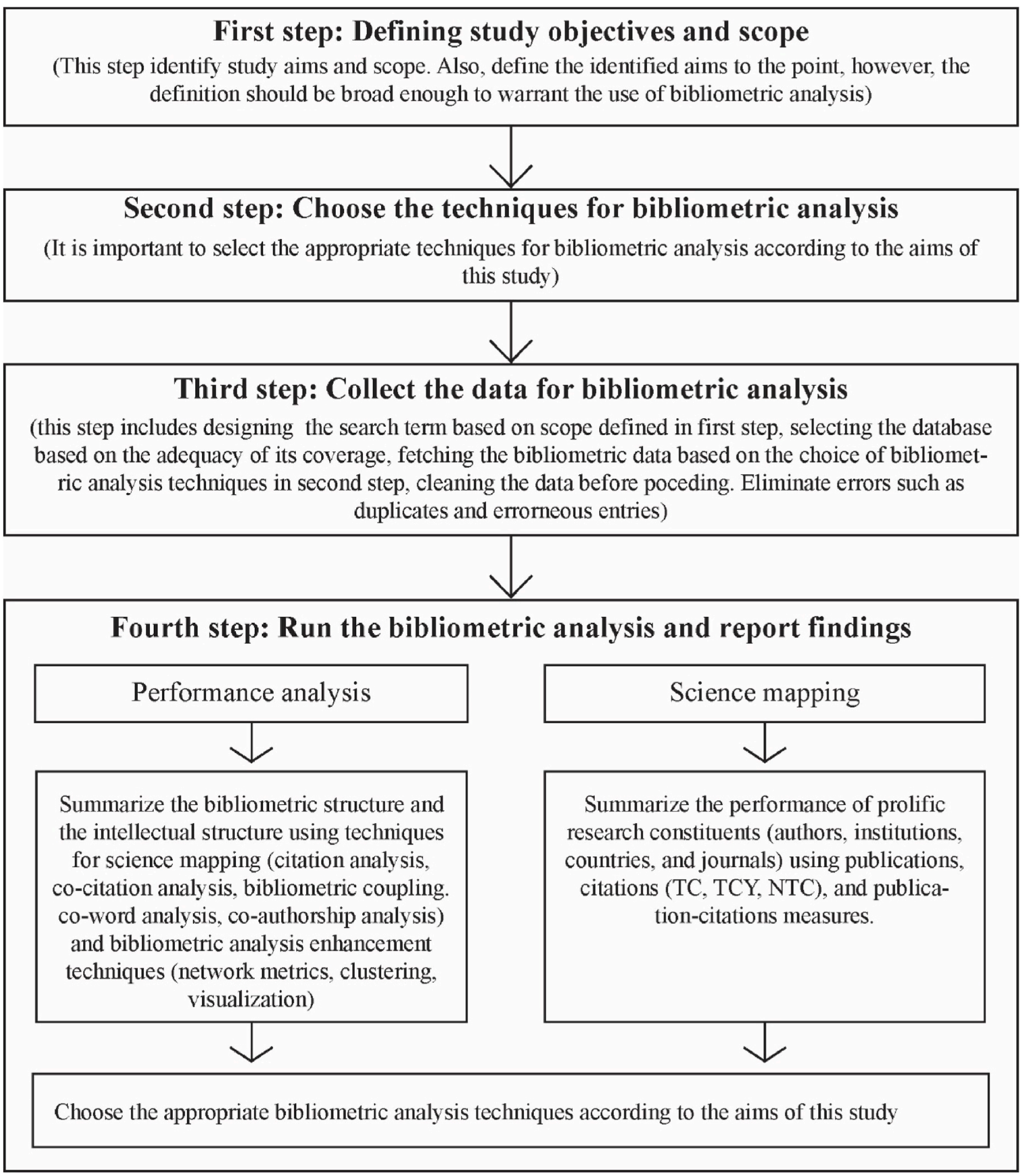

Fig. 1. Methodological framework. Notes: TC = Total Citation, TCY = Total Citation per Year, NTC = Normalized Total Citation.

3. Results and analysis

3.1. Annual scientific production

Fig. 2 presents the annual scientific production of biofuel economic research covering the period 2001 to 2022. Biofuel issues mainly started to grow rapidly in 2005 and beyond. The number of articles on the biofuel economy climbed steadily in the last 16 years. In particular, the number of publications increased substantially from 2006 to 2008. In 2007 and 2008, the number of papers was 102 and 112, respectively. The reason behind the significant increase in biofuel research was that many countries either were taken initiative to increase renewable energy programmes in 2000–2007 (Hoogeveen et al., 2009). However, there was almost more or less the same number of publications between 2008 and 2015. After 2015, the number of publications started increasing to its peak, 151 in 2019. Till now, 2019 has been the highest and most significant year regarding scientific output. However, after 2019, the number of publications on the biofuel economy is high compared to the last decade. There are legitimate reasons behind the rapid growth in biofuel economics research over the past two decades. The major reasons are reducing the impact of climate change issues, coping with higher energy demand and consumption, ensuring adequate energy supply for achieving the sustainable development goals (SDGs) and the EU Green deal.

3.2. Country scientific production and collaboration

This section presents the country-wise scientific contribution to the sustainable biofuel economy. Fig. 3 (a) shows the time-trend assessment of the countries that accomplished the most scientific production. The top 10 countries most interested in biofuel economic research are the United States (573), India (349), China (281), Brazil (210), Malaysia (152), Italy (100), the United Kingdom (100), Indonesia (99), Iran (95), and Australia (88). On the other hand, the top 10 countries in global biofuel production are the United States (1347.30), Brazil (883.70), Indonesia (283), Germany (146.30), China (142), Thailand (98.10), France (96.40), the Netherlands (83.60), Spain (70.80) and Argentina (61.60). We can see that, except for the USA, China, Brazil, and Indonesia, other top countries in scientific publications are not in the top producer of biofuels country list. But, if we see the full list of top biofuel-producing countries in Table 1, it has been found that except Malaysia, Australia, South Korea, Pakistan, and Greece, all other countries with the highest number of scientific publications are in the top biofuel-producing country list. From this argument, we infer that most countries interested in biofuel economic research have higher unit biofuel production. For example, the USA is at the top in biofuel research (573 research output) as well as biofuel production (1438 Petajoules in 2021). Somehow, there are favourable and increasing conditions for the biofuel economy in developing counties with a high potential to reduce oil imports, foster rural economic growth, and fight poverty (Adenle et al., 2013).

Indeed, the USA took the leading production position during the entire period. After 2006, it noticed a rapid growth of publications of articles by the US only. This publication rate was increased because of the Energy Policy Act that the government of their country executed in 2005. The *Energy Independence and Security Act* (EISA) *of 2007* requires a *Renewable Fuel Standard (RFS-2)* under which the US can produce 36 billion gallons of biofuel annually, mainly ethanol, by 2022. However, switching from non-renewable energy sources (fossil fuels) without introducing any economic burden is a challenging long-term issue for the US. Even though policymakers and experts usually recognise the significance of energy security, how to reach this goal and at what cost is still a contentious issue in the US. In addition, since 2007, the growth rate of publications in the Netherlands has been much faster than in the other five most important countries. Most top-ranked countries enacted the Renewable Energy Sources Act of 2006. So, research on biofuel energy has grown a lot because of the execution of laws and promotional initiatives like the Renewable Energy Medium and Long-term Development Plan from 2010 to 2020. It can be seen from Fig. 3 (a) and Table 1 that the highly efficient, productive countries had a significant role in the rapid growth of biofuel energy research, whereas biofuel is the most popular in the USA and Europe. India holds the second position in scientific output. However, not even the top 10 in the biofuel-producing countries. China has risen to second place based on scientific output. Even the situation was the same one decade ago; for example, Leu et al. (2012) demonstrated that in terms of the number of patents, North America (US, Canada), South America (Brazil), the European Union (EU) countries and some Asian countries were the countries with the largest number of biofuel patents. For the other countries involving biofuels economy, large-scale industrial commercialisation of the biofuel economy is still recommended to ensure environmental and economic sustainability (Gupte et al., 2022).

The most productive countries and regions in biofuel energy research worked collaboratively, as shown in the diagram in Fig. 3 (b). The USA played a big part in the collaboration network of with almost all productive countries and regions. Every network member has already

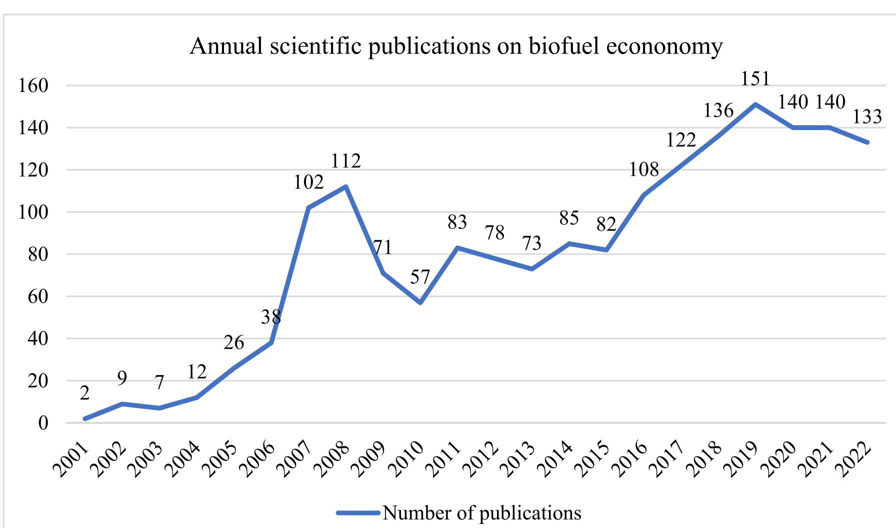

Fig. 2. Annual number of scientific published documents in 2001–2022.

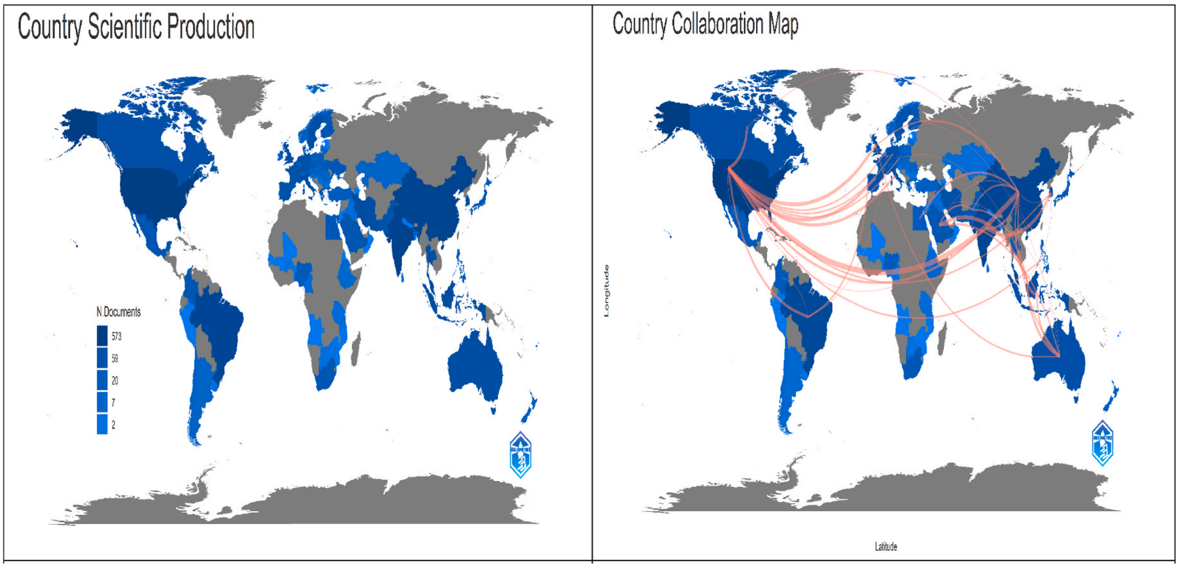

Fig. 3. Country scientific production and collaboration (follow Tables 1 and 2).

Table 1
Top countries' scientific production and biofuel production.

Region	Frequency	Country	Petajoules (in 2021)
USA	573	USA	1435.8
INDIA	349	BRAZIL	839.5
CHINA	281	INDONESIA	311.9
BRAZIL	210	CHINA	142.7
MALAYSIA	152	GERMANY	121.2
ITALY	100	FRANCE	107.0
UK	100	THAILAND	89.8
INDONESIA	99	ARGENTINA	85.6
IRAN	95	NETHERLANDS	84.6
AUSTRALIA	88	INDIA	82.9
SOUTH KOREA	86	SPAIN	71.9
NETHERLANDS	77	CANADA	48.4
SWEDEN	76	ITALY	45.8
CANADA	74	POLAND	43.3
THAILAND	72	SOUTH KOREA	32.4
GERMANY	63	COLOMBIA	28.8
FRANCE	59	SWEDEN	25.7
SPAIN	58	UNITED KINGDOM	22.7
PAKISTAN	47	BELGIUM	19.4
GREECE	38	AUSTRIA	17.4

Notes: Country scientific production data from the authors' analysis and Country-wise biofuel production data have been collected from the BP Statistical Review of World Energy (2022).

worked with the US in some way. The cooperation between the United States and China (22) is the most noticeable among them. It comes in first in terms of intensity. There are also several collaborations between the United States with Canada (12), UK (11), France (10), Italy (8), and Brazil (8). Regarding collaboration, China has the second, and Malaysia has the third highest number of collaborative research projects with many countries. Malaysia has a higher number of collaborations with Australia (10), Indonesia (10), Saudi Arabia (12). Interestingly, we affirm that most of the top carbon-emitting countries are highly concerned about biofuel research and collaboration. China, USA, India, Russia, Japan, Germany, and other countries are the top carbon-emitting countries in the list of top countries in biofuel research and collaborations. The details data of biofuel economy research collaboration is given in Table 2.

Table 2
Country collaboration.

From	Freq	To (Countries with collaboration)
USA	152	Belgium (2), Chile (2), Colombia (2), Israel (2), Thailand (2), Ukraine (2), Uruguay (2), Australia (3), Austria (3), Denmark (3), Finland (3), Iran (3), Japan (3), Portugal (3), Spain (3), Switzerland (3), Ethiopia (4), Mexico (4), Czech Republic (5), Germany (5), Korea (5), Netherlands (5), Philippines (5), India (7), Brazil (8), Italy (8), France (10), United Kingdom (11), Canada (12), China (22)
China	73	Germany (2), Greece (2), Iran (2), New Zealand (2), Finland (3), Indonesia (3), Italy (3), Japan (3), Canada (4), Denmark (4), Hong Kong (4), Korea (4), Saudi Arabia (4), Thailand (4), Pakistan (5), United Kingdom (5), Australia (6), Egypt (6), Malaysia (7)
Malaysia	70	Greece (2), Hungary (2), Iraq (2), Japan (2), Portugal (2), Thailand (2), United Kingdom (2), Nigeria (3), Bangladesh (4), Czech Republic (4), Iran (4), Korea (4), Pakistan (5), Australia (10), Indonesia (10), Saudi Arabia (12)
India	47	Australia (2), Canada (2), Czech Republic (2), Egypt (2), Ireland (2), Portugal (2), Saudi Arabia (2), Malaysia (3), Pakistan (3), Spain (3), Thailand (3), United Kingdom (3), China (7), Korea (11)
Brazil	26	France (2), Italy (2), Poland (2), Spain (3), United Kingdom (3), Colombia (4), Netherlands (4), Portugal (6)
United Kingdom	25	Austria (2), Korea (2), Netherlands (2), Pakistan (2), South Africa (2), France (3), Spain (3), Germany (4), Australia (5)
Australia	18	Canada (2), Pakistan (2), Bangladesh (4), Finland (4), Saudi Arabia (6)
France	12	Austria (2), Chile (2), Switzerland (2), Colombia (3), Finland (3)
Indonesia	12	Netherlands (2), Saudi Arabia (2), Australia (8)
Iran	12	Denmark (2), France (2), Greece (2), Iraq (2), Netherlands (2), Saudi Arabia (2)
Pakistan	10	Czech Republic (2), Hungary (2), Saudi Arabia (6)
Canada	5	Mexico (2), Germany (3)
Colombia	5	Austria (2), Chile (3)
Korea	5	Saudi Arabia (2), Pakistan (3)
Saudi Arabia	5	Egypt (2), Bangladesh (3)
South Africa	5	Botswana (2), Nigeria (3)
Germany	4	Austria (2), Switzerland (2)
Italy	4	Denmark (2), Netherlands (2)
Netherlands	4	Canada (2), Denmark (2)
Finland	3	Denmark (3)
Japan	3	Philippines (3)
Sweden	3	Finland (3)
Spain	2	Mexico (2)

3.3. Most cited countries

Citation impact metrics are increasingly important in assessing research impact, and researchers are interested in scientometric literature (Waltman, 2016). This study analyses the citation impact of sustainable biofuel economy research. Fig. 4 presents the most cited countries or territories ranked based on the number of single-country total citations (TC) and average article citations (AAC). We only present the top 20 countries in Fig. 4, but Table 3 in the appendix shows the rest of the countries. The United States (5049) is the most cited country, whereas Malaysia and India are second and third with 2454 and 2358 citations, respectively. Somehow, the dispersion between USA and Netherlands is quite noticeable in citations (nearly double). China is in the fourth place (1990), and Spain is in the fifth place (1357) for the number of citations. We affirm that a possible explanation behind the number of citations given here is that although many countries are researching the biofuel economy, the most cited countries have more meaningful research and societal impact.

3.4. Most popular sources

It is also imperative to understand which journals are more focused on publishing papers in the area of biofuel economic and which research fields are the focus of those journals. This information on publication sources will help researchers read more papers and submit papers to those journals. Therefore, this study analyses primary sources of sustainable biofuel economy research. We list the scientific publication sources of the top 25 journals with the number of articles published on biofuels. Table 4 presents the list of primary sources with the number of articles published on biofuels. This table includes only 25 journals, and the extended list is in the appendix (please see Table 5). The analysis of the primary sources indicates a predominance of business, management, accounting, economics, econometrics, finance, energy, environmental science, and agriculture categories journals (please see Table 4). The first two journals, the Journal of Cleaner Production, account for nearly 26% of the relevant papers (a total of 471). The following nine journals, Fuels and Lubes International (total 149–8%), Petroleum Review (total 73–4%), Frontiers in Energy Research (total 62–3%), Energy Economics (total 41–2%), International Journal of Technology (total 30–2%), Resources, Conservation and Recycling (total 27–2%), Petroleum Economist (total 26–1%), American Journal of Agricultural Economics (total 24–1%), Environment, Development and Sustainability (total 24–1%). Some books also published very relevant chapters on the sustainable biofuel economy.

3.5. Most globally cited documents

This study also presents the top-cited papers in the field of biofuel economy research. Some literature limits this list to a minimum or maximum citation number; for example, Krishen et al. (2021) determined the list within a minimum of 20 citations in their analysis. Most papers on biofuel topics have many citations; that is why we do not limit by citation number; instead, we present the top 50 most cited articles. These published research articles significantly discussed regarding the importance of the biofuel economy in different aspects. This study mentions the most globally cited research articles that have significant social and research impact. A list of the top 50 highest-cited articles is given in Table 6. The rest of the list is presented in Table 7 in the appendix, including authors' information, publication year, publication sources (journal), digital object identifier (DOI), total citations, yearly citations, and normalized total citations.

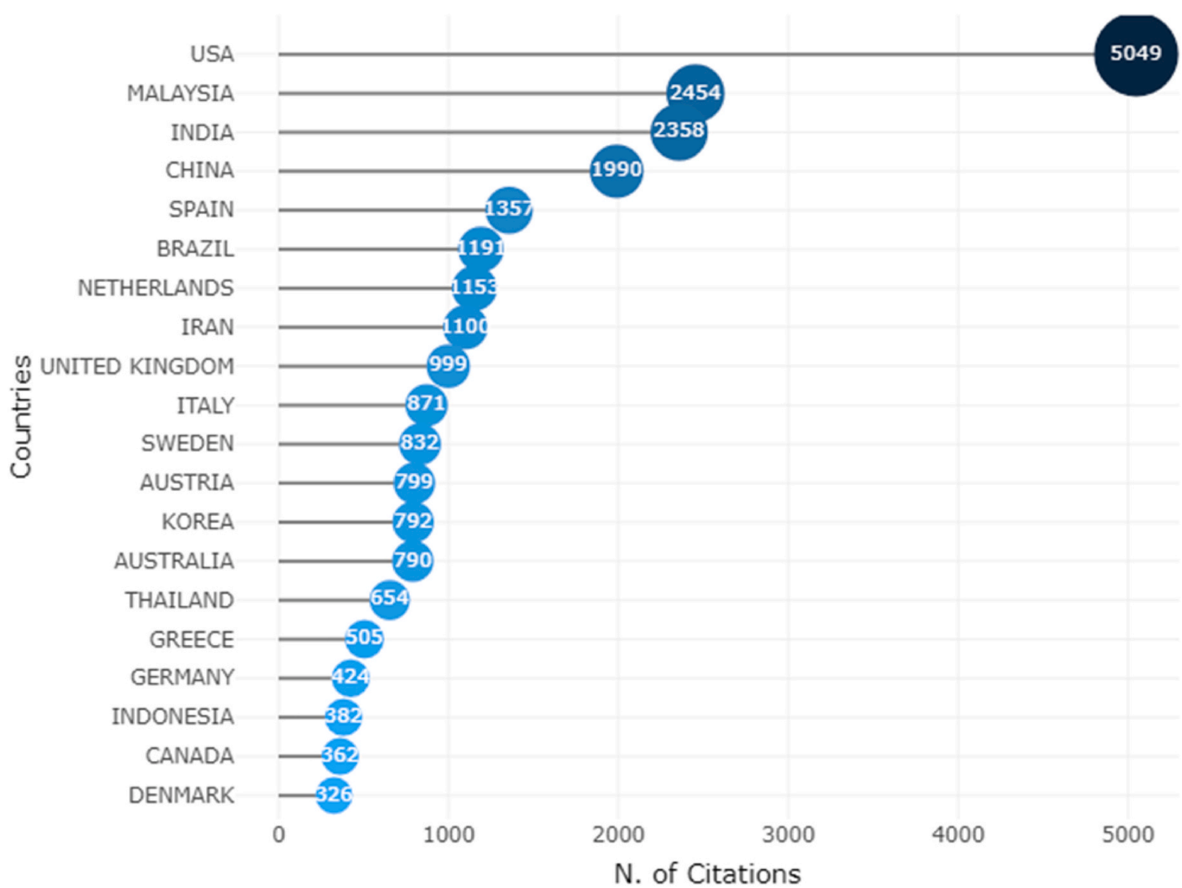

Fig. 4. Countries biofuel economy research citation (social impact).

Table 4
Primary source journal more concerns with biofuel economy.

Sources	#	%	SC	IF
JOURNAL OF CLEANER PRODUCTION	471	26%	BMA, E, EnS	11.072
FUELS AND LUBES INTERNATIONAL	149	8%	EEF, E	–
PETROLEUM REVIEW	73	4%	BMA, E	–
FRONTIERS IN ENERGY RESEARCH	62	3%	EEF, E	3.858
ENERGY ECONOMICS	41	2%	EEF, E	9.252
INTERNATIONAL JOURNAL OF TECHNOLOGY	30	2%	BMA, Eng	–
RESOURCES, CONSERVATION AND RECYCLING	27	2%	EEF, EnS	13.716
PETROLEUM ECONOMIST	26	1%	BMA, E	–
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS	24	1%	ABS, EEF	3.028
ENVIRONMENT, DEVELOPMENT AND SUSTAINABILITY	24	1%	EEF, EnS, SS	4.080
INTERNATIONAL JOURNAL OF SCIENTIFIC AND TECHNOLOGY RESEARCH	23	1%	BMA, Eng, SS	–
INTERNATIONAL JOURNAL OF BIOLOGICAL MACROMOLECULES	20	1%	BGMB, EEF, E, M	8.025
AGBIOFORUM	17	1%	ABS, BGMB, EEF	–
CLEAN TECHNOLOGIES AND ENVIRONMENTAL POLICY	16	1%	BMA, EEF, EnS	4.700
ECOLOGICAL ECONOMICS	16	1%	EEF, EnS	6.536
CHEMICAL MARKET REPORTER	15	1%	BMA, C	–
THE LAW AND POLICY OF BIOFUELS	15	1%	E, EnS	–
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY	14	1%	EEF, E	–
FOOD POLICY	11	1%	ABS, EEF, EnS, SS	6.08
FOREST POLICY AND ECONOMICS	11	1%	ABS, EEF, EnS, SS	4.259
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	11	1%	BMA, P	10.884
APPLIED ECONOMIC PERSPECTIVES AND POLICY	10	1%	EEF, SS	2.779

Notes: Authors' illustration [SC = Scimago Category, E = Energy, EnS = Environmental Science, BMA = Business, Management and Accounting, Eng = Engineering, EEF = Economics, Econometrics and Finance, ABS = Agricultural and Biological Sciences, BGMB = Biochemistry, Genetics and Molecular Biology, SS = Social Sciences, P = Psychology, DS = Decision Sciences, CE = Chemical Engineering, M = Medicine, C = Chemistry, PA = Physics and Astronomy].

3.6. Most relevant words with tree map

Fig. 5 shows most significant word focus and tree map from abstract on biofuel energy. Previous studies investigated several essential vital points in biofuel energy and economics research. It is critical to figure out how these important aspects are progressing. According to Yaoyang and Boeing (2013), biofuel energy hotspots are items based on intellectual keyword connections such as biofuel conversion routes, conversion process, fuel cells, and lifetime evaluation. In this study, we evaluate and analyse abstract from retrieved publications around hot topics in biodiesel, production, biofuels, energy, emissions, bioethanol, economic, prices, renewable, development, environmental, policy, research, impact, sustainability, and some other aspects. This study links biofuel with significant relationships to the economy, policies, emissions, production, prices, development, and sustainability, taking into account the abstract focus words used in earlier studies. As we can see, authors from economics, food security, supply chain management, and other fields are working on biofuel research in addition to fundamental biofuel and energy research.

3.7. Research focus and growth of the biofuel economy

Fig. 6 shows the growth of research focus on the biofuel economy from 1998 to 2022. Due to overpopulation and economic growth, many countries face the need for non-renewable fossil fuels (Saravanan et al.,

Table 6
Most global cited documents (extension available Table 7 in appendix).

Author(s), Year	DOI	TC	TCY	NTC
CHERUBINI F, 2009	10.1016/j.resconrec.2009.03.013	665	44.33	20.35
BÖRJESSON P, 2011	10.1016/j.jclepro.2010.01.001	256	19.69	14.34
RAHEEM A, 2018	10.1016/j.jclepro.2018.01.125	253	42.17	11.37
VAN KASTEREN JMN, 2007	10.1016/j.resconrec.2006.07.005	252	14.82	35.26
FAROOQ M, 2013	10.1016/j.jclepro.2013.06.015	233	21.18	10.30
HUANG Y, 2010	10.1016/j.tre.2010.03.002	221	15.79	7.71
CUELLAR-BERMUDEZ SP, 2015	10.1016/j.jclepro.2014.03.034	204	22.67	10.48
LIEW WH, 2014	10.1016/j.jclepro.2014.01.006	188	18.80	6.53
COSTANTINI V, 2015	10.1016/j.respol.2014.12.011	182	20.22	9.35
SUURS RAA, 2009	10.1016/j.techfore.2009.03.002	182	12.13	5.57
CHEN CW, 2012	10.1016/j.tre.2011.08.004	178	14.83	5.72
CHUAH LF, 2017	10.1016/j.jclepro.2016.05.017	176	25.14	6.81
SARAVANAN AP, 2018	10.1016/j.jclepro.2018.05.033	174	29.00	7.82
ZILBERMAN D, 2013	10.1093/ajae/aas037	172	15.64	7.60
BANSE M, 2008	10.1093/erae/jbn023	170	10.63	17.74
TEO SH, 2019	10.1016/j.jclepro.2018.10.107	167	33.40	8.98
DE GORTER H, 2010	10.1093/aepp/ppp010	166	11.86	5.79
ZHONG L, 2020	10.1016/j.ijbiomac.2020.02.258	159	39.75	9.33
BANERJEE A, 2009	10.1016/j.resconrec.2009.04.003	155	10.33	4.74
SERRA T, 2013	10.1016/j.eneco.2013.02.014	153	13.91	6.76
ONG HC, 2019	10.1016/j.jclepro.2019.02.048	151	30.20	8.12
DE GORTER H, 2009	10.1111/j.1467–8276.2009.01275.x	144	9.60	4.41
RIZWANUL FATTAH IM, 2020	10.3389/fenrg.2020.00101	141	35.25	8.28
ROSEGRANT MW, 2008	10.1111/j.1467–9353.2008.00424.x	141	8.81	14.72
SANJID A, 2014	10.1016/j.jclepro.2013.09.026	140	14.00	4.86
MORAIS S, 2010	10.1016/j.jclepro.2010.04.014	140	10.00	4.88
HERTEL TW, 2010	10.5547/ISSN0195-6574-EJ-Vol31-No1-4	136	9.71	4.74
ARIZA-MONTOBBIO P, 2010	10.1016/j.ecolecon.2010.05.011	135	9.64	4.71
BÓRAWSKI P, 2019	10.1016/j.jclepro.2019.04.242	134	26.80	7.21
MACOMBE C, 2013	10.1016/j.jclepro.2013.03.026	133	12.09	5.88
CAVALETT O, 2010	10.1016/j.jclepro.2009.09.008	132	9.43	4.60
GURGEL A, 2007	10.2202/1542–0485.1202	131	7.71	18.33
KEENEY R, 2009	10.1111/j.1467–8276.2009.01308.x	129	8.60	3.95
MOAZENI F, 2019	10.1016/j.jclepro.2019.01.181	128	25.60	6.88
HARDING KG, 2008	10.1016/j.jclepro.2007.07.003	125	7.81	13.05
AITKEN D, 2014	10.1016/j.jclepro.2014.03.080	122	12.20	4.23
AHMED W, 2018	10.1016/j.jclepro.2018.02.289	119	19.83	5.35
BABAZADEH R, 2017	10.1016/j.omega.2015.12.010	116	16.57	4.49
HALL J, 2009	10.1016/j.jclepro.2009.01.003	115	7.67	3.52
NANAKI EA, 2012	10.1016/j.jclepro.2011.07.026	114	9.50	3.66
DHINESH B, 2018	10.1016/j.jclepro.2018.06.002	111	18.50	4.99

(continued on next page)

Table 6 (*continued*)

Author(s), Year	DOI	TC	TCY	NTC
SILALERTRUKSA T, 2012	10.1016/j.jclepro.2011.07.022	110	9.17	3.53
HAYYAN A, 2014	10.1016/j.jclepro.2013.08.031	106	10.60	3.68
KIWJAROUN C, 2009	10.1016/j.jclepro.2008.03.011	104	6.93	3.18
LAKSHMIKANDAN M, 2020	10.1016/j.jclepro.2019.119398	103	25.75	6.05
KRISTOUFEK L, 2012	10.1016/j.eneco.2012.06.016	102	8.50	3.28
GHADERI H, 2018	10.1016/j.jclepro.2017.12.218	101	16.83	4.54
TANG Y, 2013	10.1016/j.jclepro.2012.11.001	100	9.09	4.42
TALENS L, 2007	10.1016/j.resconrec.2006.10.008	99	5.82	13.85
SHRIVASTAV A, 2010	10.1016/j.ijbiomac.2010.04.007	98	7.00	3.42

Notes: Authors' analysis [TC = Total Citation, TCY = Total Citation per Year, NTC = Normalized Total Citation].

2022). Thereby, a wide range of biofuel economy fields are growing day by day,agriculture, biodiesel, bioenergy, bioethanol, biofuel, biofuel policy, biomass, biomass energy, climate change, energy, energy policy, ethanol, greenhouse gas emission, land use, renewable energy, sustainability, sustainable development, wood biomass, and so on. Due to the rapid growth of biofuel economic issues, examining the burgeoning literature on sustainable biofuel economy is imperative. This growth perspective can provide a practical perspective on energy research development and progress. This progress has a significant impact on both the country-specific economy and the global economy. Subramaniam and Masron (2021) support the growth of biofuel and demonstrate that biofuel growth is positive for decreasing inequality, reducing poverty, a promoting economic growth in developing countries. These three issues are also directly related to SDGs, leading to a sustainable biofuel economy. This study also confirms that all the growing issues of the biofuel economy are also connected to sustainable development. Fig. 6 illustrates that sustainable biofuel economy forces have been getting more and more attention worldwide.

3.8. *Co-occurrence assessment*

Fig. 7 presents the co-occurrence assessment and connection of biofuels with other issues. We prepare this co-occurrence network from all keywords, including keyword plus and author's keyword; the minimum number of occurrences of keywords is selected 10. According to Fig. 7, the forces of this co-occurrence assessment are economic growth, environment, carbon emission, land-use change, greenhouse gas emission, impacts, market, food, emission, food security, policies, price, agriculture, costs, climate change, economics, supply chain, management, electricity, technology, sustainable development, challenges, performance, sustainability, innovation, bioethanol, China, US, uncertainty, and so on. From the above forces, biofuel has a significant connection with the economy and SDGs forces such as economic growth, environment, carbon emission, land-use policy, greenhouse gas emission, food security, agriculture, climate change, electricity, technology, innovation, and more importantly sustainability and sustainable development.

3.9. *Thematic map of biofuel research focus*

We present a thematic mapping of the biofuel and economic transition in Fig. 8 with the authors' keyword mapping. According to the authors' keyword mapping, there are eight related circles such as (i) biodiesel, biofuel, ethanal, (ii) biofuel, sustainability, bioenergy, (iii) greenhouse gas emissions, land use, biofuel policies, (iv) bioethanol, fermentation, pre-treatment (v) transesterification, waste cooking oil, biodiesel production (vi) crude oil, food, (vii) district heating, transport sector, (vii) indirect land use change. Finally, we conclude from the

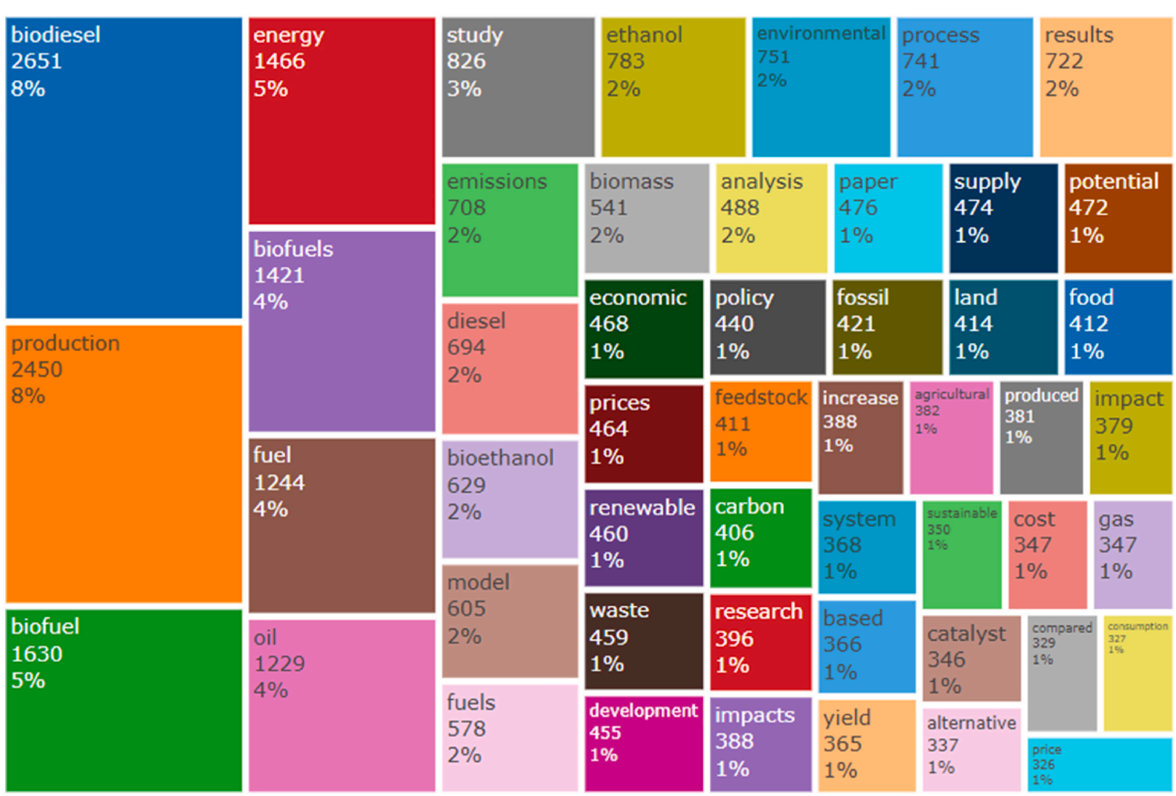

Fig. 5. Most significant words focus and tree map from abstract.

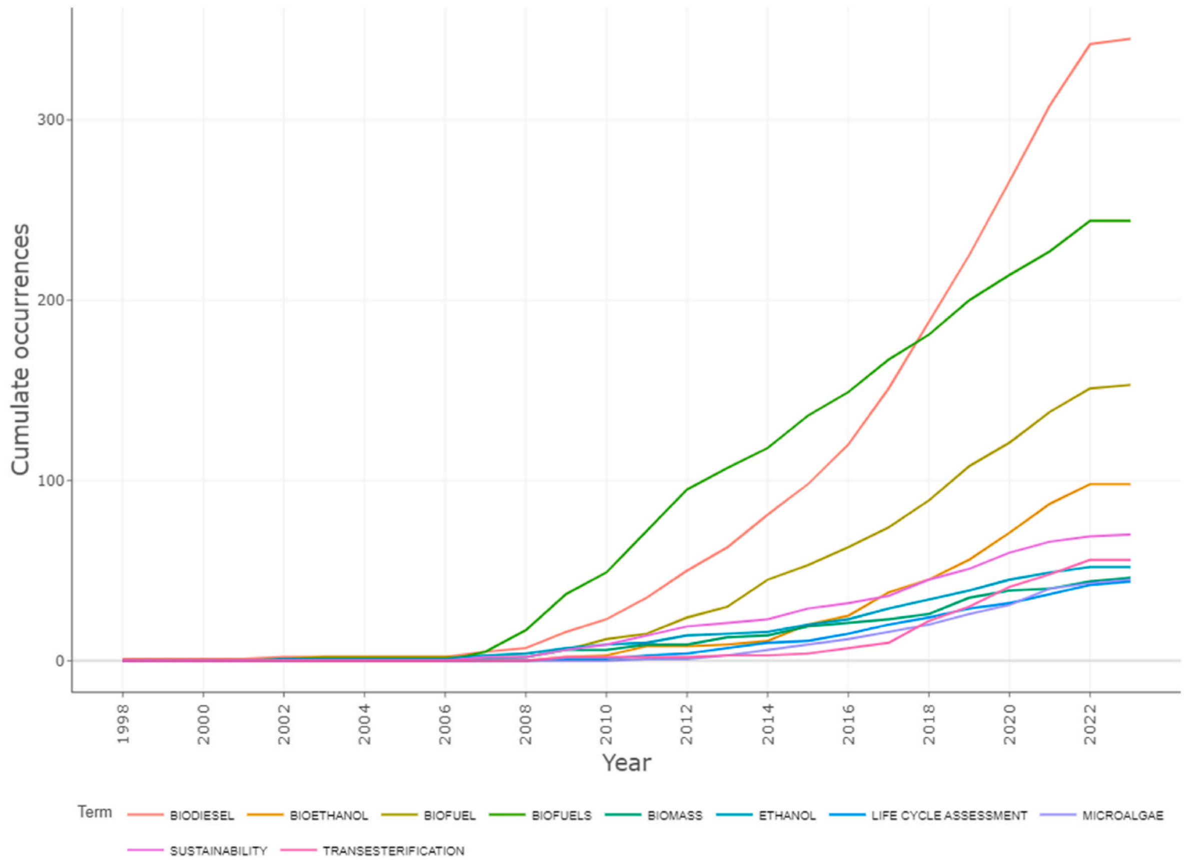

Fig. 6. Research focus and growth of the biofuel economy.

thematic map that biofuel and bioenergy are significantly connected with sustainability.

3.10. Thematic evaluation

We present the thematic evaluation of biofuel economy research. The total period is divided into 1998 to 2016 and 2017 to 2022. We discuss how the biofuel economy research focus connects each area over time. In the earlier period, biofuel economy research was focused on life cycle assessments, greenhouse gas emissions, biofuel policy, uncertainty, and food securities. Biofuel got high attention from researchers and policymakers in the last decade. Also, bioenergy, life cycle assessments, greenhouse gas emission, biofuel policy, uncertainty, food security, and renewable fuel standards attracted scholars in the second segment from 2017 to 2022. Table 8 (appendix) presents the details of thematic evaluation results in the following sections, and further, the thematic evaluation map is also illustrated in Fig. 9.

3.11. Conceptual structure map

This study also analyses the conceptual structure map according to the *Multiple Correspondence Analysis (MCA)* method and *Multidimensional Scaling (MDS)* technique, shown in Fig. 10. We find two relational structures; the big one is red, and the smaller one is blue. The red structure contains twenty-seven (27) keywords, and the blue structure includes only three (3) keywords. According to the first structure, the most prominent sustainable economic factors connected to biofuel are transportation, food security, climate, land-use policy implications, biofuel policy, agriculture, environment, and sustainable development. The MDS method has two relational structures in the second conceptual structure map. The smaller one is the same as the first map (MCA). According to the MDS technique, the bigger map contains 18 keywords. The red map shows biofuel is structured to economic variables such as innovation, energy, policy, environment, poverty, economic growth, greenhouse gas emission, and agriculture.

4. Discussion, challenges, and policy implications

4.1. Discussion

This study focuses on the inclusive development level due to the significance of biofuels. Our bibliometric findings confirmed the link of biofuel with UN SDGs. Some studies also support the findings from the empirical analysis. For example, Costa and Oliveira (2022) demonstrated that working in the biofuel production industry improved workers' well-being, particularly by increasing income, working longer hours, and reducing social inequalities. The social life cycle is also highly recommended to consider during the national biofuel policies. Biofuels can potentially help to reduce economic distress in different ways. Biofuels lessen the dependency on fossil fuels, facilitating conversion toward a zero-petroleum transportation system. Also, countries may become self-sufficient instead of fossil fuels (for example, oil, gas, and coal) by using biomass, which is widely available and easily turned into renewable energy.

The key issue for a sustainable biofuel economy is better policies for a better society. Our findings also show that policies on biofuels, energy, renewable energy, environment, climate policy, and land use are also highly focused on different aspects. We confirm that good biofuel policies are essential to obtain the best economic benefits from biofuels. Good biofuel policies always work as strong hedging against uncertainties (Alizadeh et al., 2020). Initially, government policy on a sustainable biofuel economy to reduce the adverse impact of global climate change (Eswaran et al., 2010; Sorda et al., 2010). Policy instruments should target both biofuel production's positive and negative

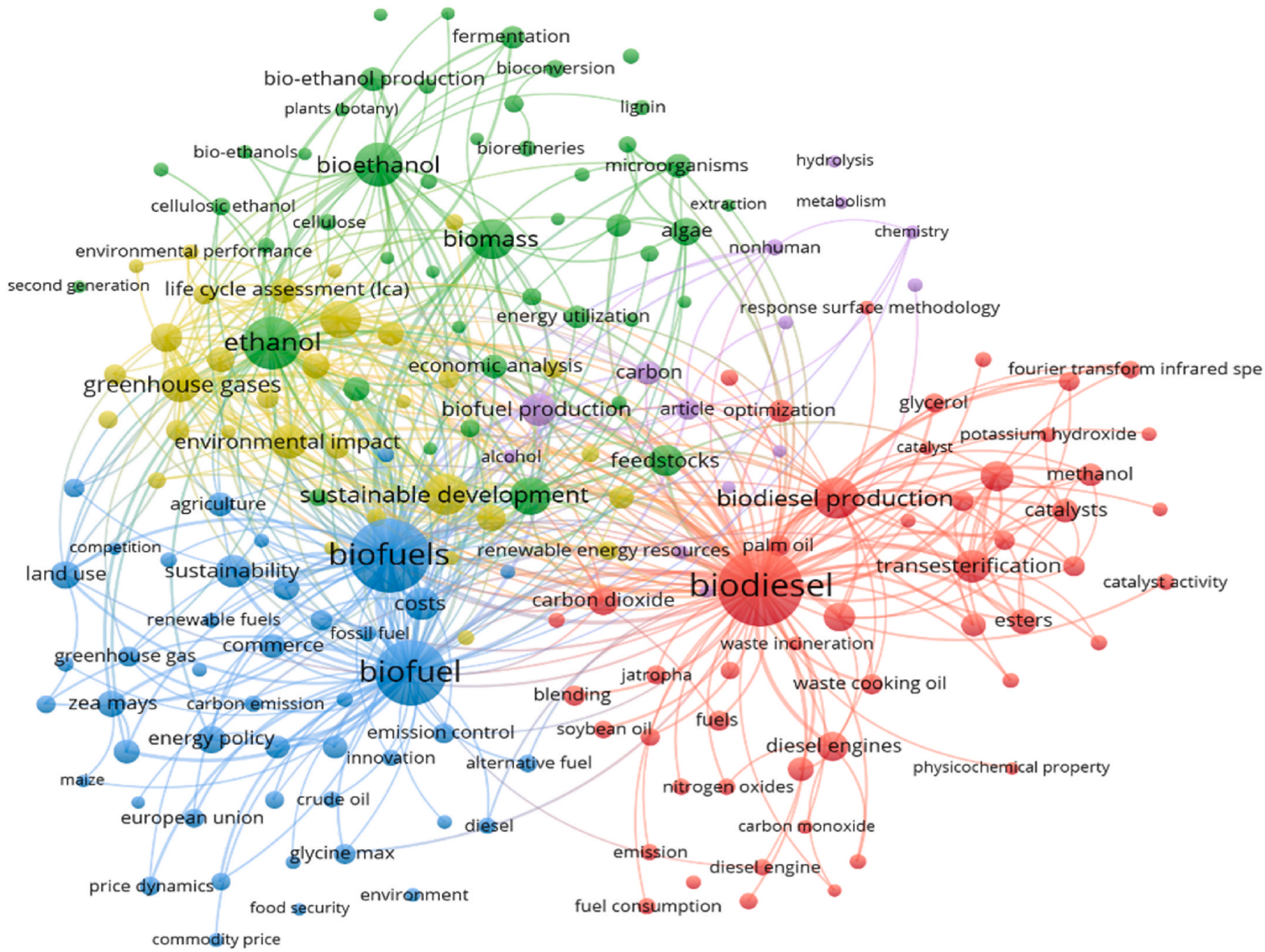

Fig. 7. Co-occurrence assessment of biofuel economy (minimum occurrence 15). Notes: Author's illustration using VOSviewer [Co-occurrence, all keywords, the minimum number of occurrence of keywords (15), of the 8278 keywords, 188 meet the threshold, cluster 6, links 9148, total link strength 35,222, max length 0, max line 500].

impacts rather than the product itself. A good combination framework of policy incentives and efficient technologies further reduces biofuels' social and environmental footprint, thus contributing to sustainable development (Ahmed, 2021; Sandesh and Ujwal, 2021). Both bioenergy research and policy solve the existing and potential problems in the entire biofuel economy. Necessary policy development and implementation are important to ensure biofuel expansion To get more benefits from the biofuel economy and meet the sustainable energy demand in future (Afionis and Stringer, 2020; Sandesh and Ujwal, 2021).

Less developed countries are still far behind sustainable biofuel economies, so sustainable biofuel economies can only be ensured if all regions benefit from biofuels in an accessible and cost-effective manner. We believe large-scale expansion is important globally, so large-scale green technology innovation in biofuel production is a prominent factor. However, advanced technologies are essential for efficient biofuel production to reduce the use of non-renewable fuels in the global economy and achieve the stability of renewable energy in the future.

Some issues also need to be considered as the adverse effects of sustainable biofuel expansion. Such as, the drive for biofuels may lead to huge changes in the landscape, turning marshes and forests into agricultural land. This may have a detrimental effect on biodiversity and lead to habitat degradation. Also, food prices rise, and local communities face food shortages due to the frequent competition for land and resources between the production of biofuels and food crops, especially in developing countries. Additionally, significant amounts of water are required to manufacture biofuels, increasing competition for existing scarce water resources, especially in areas with a water shortage. Although the development of some biofuels can result in larger emissions of glasshouse gases than other biofuels, this is especially true if the land utilised to cultivate the biofuel crops was previously used for wetlands or forests. Finally, the energy yields of biofuels are often lower than those of fossil fuels, requiring more resources (such as land, water, and other natural resources) to produce the same quantity of energy.

4.2. Challenges of biofuel economic promotion

Despite the promising potential, several technical challenges must be considered for the sustainability of the biofuel economy, its commercialisation, and policy implications.

- The main commercial challenge of biofuel production is the high production cost, which determines the fuel price. In most countries, biofuel costs multiple times that of fossil fuels such as gasoline and diesel (Clemente, 2015; Luterbacher and Luterbacher, 2015; Oregon State University, 2011). Huang et al. (2010) underscore the need to incorporate cost reductions across the biofuel supply chain into the master planning. To incorporate biofuel cost reduction, technological advances support lower production costs, leading to biofuels

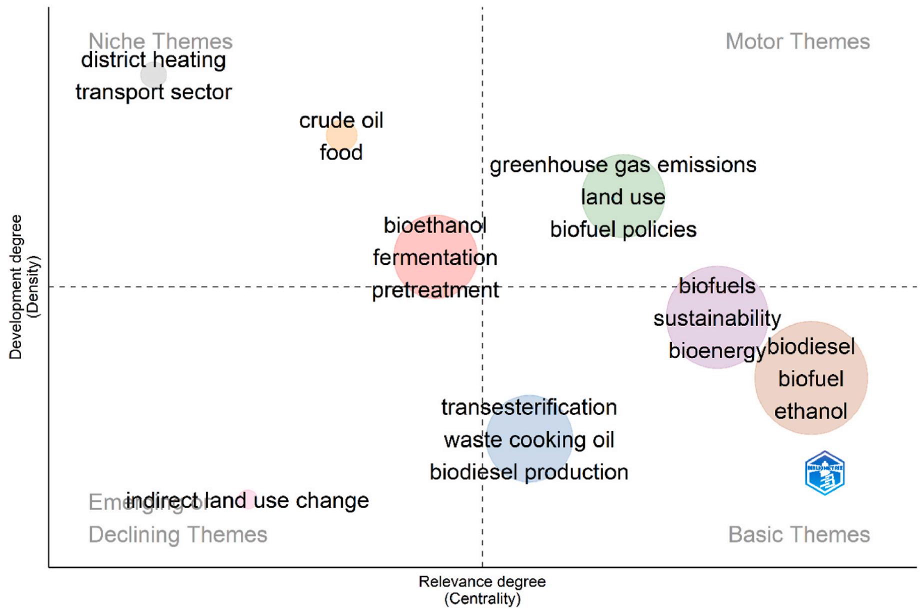

Fig. 8. Thematic map of biofuel research focus.

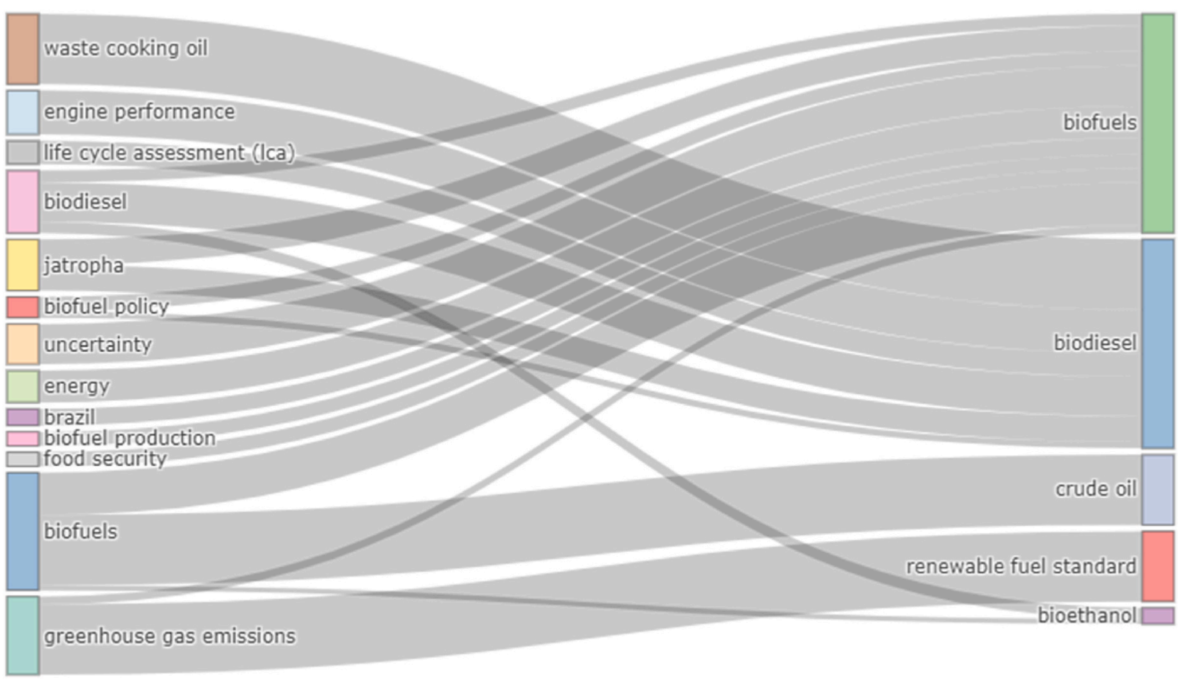

Fig. 9. Thematic evaluation of biofuel research.

becoming one of the main renewable energy sources (Jeswani et al., 2020; Lee and Lee, 2008; Yang et al., 2021). Therefore, advanced biodiesel and bioethanol production technologies are required to increase biofuel production yield. But, the advance technology implementation progress is also a concern for high costs.

- Fiscal and regulatory policies to attract investors and fund biofuel research from biomass feedstock are also challenges. There is a big pitfall regarding the cost of policy implications. The cost of policy implications regarding biofuel production and expansion is a key cost concern for governments worldwide. Due to the high cost of project implementation and infrastructure development, the private sector may not be able to finance the entire project. In some circumstances, accessing a loan or financing support to start investment in the biofuel business is also difficult. Somehow, such support is intended to empower prospective biofuel business entrepreneurs.
- Insufficient or low infrastructure development works as a problem behind the growth of the biofuel economy. Funding from other sectors is also highly required to promote the biofuel economy. The government must put in place standard policies that will serve as a framework for other stakeholders, such as industries, private investors, research institutes, and other related parties, to contribute their fair share to the development of the biofuel sectors. The public's tendency to switch from fossil fuels (gasoline and diesel) to biofuels in the road transport sector is significant to the implementation's success.

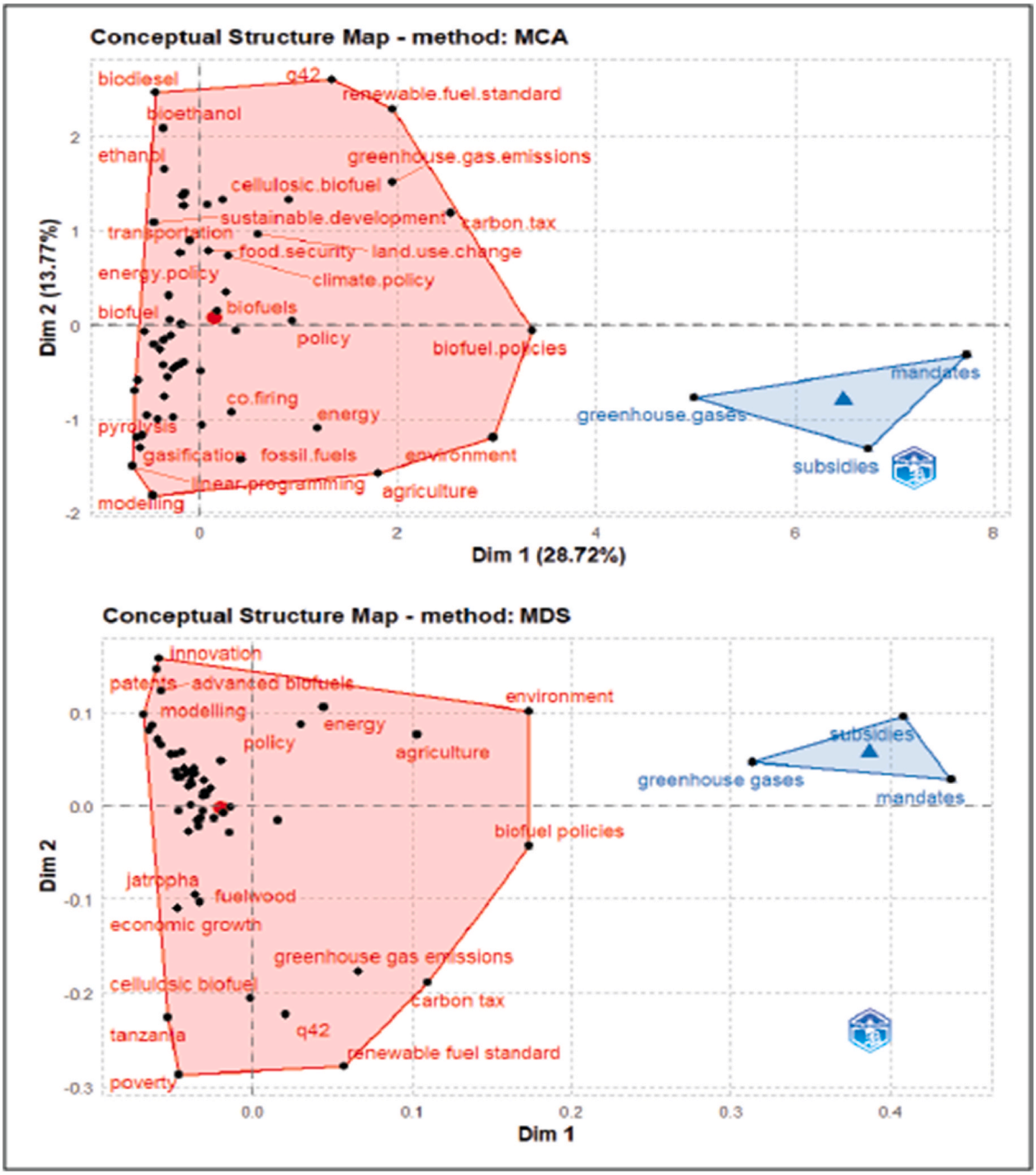

Fig. 10. Conceptual structure map.

- The primary challenge for biofuel production has been its promotion, particularly through subsidies. The commercialisation of biofuels faces several challenges. Improving farming practices to increase feedstock quality and yield and providing enabling infrastructures, including power, roads, and water, are also challenges.

Overall, the study recommends the policy that promoting the bioenergy economy requires overcoming significant challenges with farmland competition, increasing food prices, difficulties in advance technological progress, impediments in infrastructure development, and disputes implementation of policies.

5. Conclusion

Biofuels have real economic effects. The in-depth bibliometric analysis of the sustainable biofuel economy was missing from the literature. This study provides up-to-date, consistent and reliable data to achieve its objective. The study's results confirm that, in most cases, developed economies are more conscious of a sustainable biofuel economy. Also, the countries that follow the renewable energy sources act are highly concerned about biofuel energy development. The United States notably plays an important role in the cooperative network among the topmost biofuel-productive countries. Every member of the network already cooperates with the United States in some way. Among them, US-China cooperation is the most important. In addition, the United States has the highest social impact on biofuel research among the countries producing biofuel energy. Another key finding of this study is that the highlighted focuses of a sustainable biofuel economy are poverty reduction, which can be linked to SDG 1; agriculture development which can be linked to SDG 2; renewable energy production, which can be linked to SDG 7, economic growth that can be linked to SDG 8, climate change policy, environmental protection, carbon emission, greenhouse gas emission those can be linked to SDG 13, land use policy that can be linked to SDG 15, and trade, technological innovations, and development that can be linked to SDG 17. We infer that biofuel will significantly influence the economy and other related circumstances such as policies, management, technological development, sustainability, and innovations. The main contribution is to show particular priorities for a sustainable biofuel economy that directly and significantly influences the environment and energy economics concerns for the ordinary people and the governments for best utilisation.

6. Future research direction

This study suggests future research on a sustainable biofuel economy, focusing on specific SDG goals such as SDG-1, SDG-2, SDG-7, SDG-8, SDG-13, SDG-15, and SDG-17, which are burning issues worldwide. Also, research on cost-effective biofuel production with technological progress should highly emphasise because it significantly reduces the negative impact on environmental quality. This study focuses only on the Bibliometric analysis of sustainable biofuel economic. Still, there is less literature review on the biofuel economy in the SDGs context. This study suggests two other potential research questions that need to be accomplished in future research. First, *How much will it cost to promote bioenergy rapidly?* And *What is the impact of the industrial transformation of bioenergy?* Future studies may also compare how bioethanol and biodiesel contribute to sustainable economies, SDGs, and climate change mitigation. Besides, it should further discuss how to addressthe existing challenges for achieving sustainable biofuel economies globally, particularly in developing countries. There is one limitation of the present manuscript. In previous versions, conceptual structure maps were analyzed using biblioshiny, however, newer versions of biblioshiny do not allow analysis of conceptual structure maps. Therefore, this study uses the previous version (data as of December 2021).

Credit author statement

Morshadul Hasan: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization, Review comment addressing, and Editing. **Mohammad Zoynul Abedin:** Editing, and Proofreading. **Mohammad Bin Amin:** Draft Writing Support. **Md. Nekmahmud:** Review comment addressing, and Proofreading. **Judit Oláh:** Supervision, Funding, and Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

Project no. 132805 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the K_19 funding scheme.

Appendix

Bibliometrix Programming details:

The entire process was conducted using the software *R* (version 4.2.1–2020-06-23 urct) and *R Studio.* First of all, we installed the “bibliometrix” package in R Studio. This package is one of the most effective packages for “bibliometrix” research. To install the package, we used the command “install.packages (“bibliometrix")”. In the second steps, we run “bibliometrix” package using the command “library (bibliometrix)”. After opening the “bibliometrix” library, the package is ready for use. In the third steps, we opened the web based software Biblioshiny by using command “Biblioshiny ()” to analyse bibliometric data. The internet browser will open a new window automatically after clicking “Biblioshiny ()” command. Then we converted the collected “BibText” file from Scopus to excel. Finally, the single excel file was used to analyse operating different graphical user interface option using Biblioshiny.

Table 3
Most cited countries

Country	TC	AAC	Country	TC	AAC
USA	5049	22.44	SOUTH AFRICA	228	19.00
MALAYSIA	2454	42.31	SWITZERLAND	225	32.14
INDIA	2358	21.63	JAPAN	211	21.10
CHINA	1990	21.40	COLOMBIA	204	22.67
SPAIN	1357	45.23	HUNGARY	188	47.00
BRAZIL	1191	14.70	POLAND	142	23.67
NETHERLANDS	1153	37.19	NEW ZEALAND	140	23.33
IRAN	1100	29.73	EGYPT	115	23.00
UNITED KINGDOM	999	24.98	IRELAND	100	16.67
ITALY	871	21.77	PHILIPPINES	85	14.17
SWEDEN	832	28.69	NIGERIA	81	7.36
AUSTRIA	799	133.17	BRUNEI	74	74.00
KOREA	792	21.41	SAUDI ARABIA	72	14.40
AUSTRALIA	790	32.92	ARGENTINA	65	21.67
THAILAND	654	28.43	PAKISTAN	65	9.29
GREECE	505	33.67	LITHUANIA	64	32.00
GERMANY	424	14.62	NORWAY	58	9.67
INDONESIA	382	10.91	LATVIA	57	57.00
CANADA	362	13.92	CROATIA	53	26.50
DENMARK	326	32.60	BELGIUM	46	9.20
CZECH REPUBLIC	318	35.33	CHILE	31	15.50

(*continued on next page*)

Table 3 (*continued*)

Country	TC	AAC	Country	TC	AAC
FRANCE	318	17.67	SLOVAKIA	30	6.00
MEXICO	312	22.29	ANTIGUA	24	24.00
PORTUGAL	305	25.42	ESTONIA	19	19.00
FINLAND	228	19.00	ANGOLA	17	17.00

Notes: TC = Total Citation; AAC = Average Article Citation.

Table 5
Primary source journal (minimum observation 3)

SOURCES NAME	ARTICLES QUANTITY
TRANSPORTATION RESEARCH PART E: LOGISTICS AND TRANSPORTATION REVIEW	10
INTERNATIONAL JOURNAL OF ENERGY, ENVIRONMENT AND ECONOMICS	9
INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY AND ENGINEERING	9
AGRICULTURAL ECONOMICS (UNITED KINGDOM)	8
JOURNAL OF AGRICULTURAL AND FOOD INDUSTRIAL ORGANIZATION	8
GENETIC ENGINEERING AND BIOTECHNOLOGY NEWS	7
GLOBAL BIOETHANOL: EVOLUTION, RISKS, AND UNCERTAINTIES	7
INTERNATIONAL JOURNAL ON EMERGING TECHNOLOGIES	7
AGREKON	6
AGRICULTURAL BIOMASS BASED POTENTIAL MATERIALS	6
AGRICULTURAL ECONOMICS (CZECH REPUBLIC)	6
EASTERN-EUROPEAN JOURNAL OF ENTERPRISE TECHNOLOGIES	6
EUROPEAN REVIEW OF AGRICULTURAL ECONOMICS	6
INTERNATIONAL JOURNAL OF BIOTECHNOLOGY	6
JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS	6
NATURAL RESOURCE MANAGEMENT AND POLICY	6
REVIEW OF AGRICULTURAL ECONOMICS	6
CLIMATE CHANGE ECONOMICS	5
ECONOMIST	5
ECONOMIST (UNITED KINGDOM)	5
ENVIRONMENTAL AND RESOURCE ECONOMICS	5
INTERNATIONAL JOURNAL OF LOGISTICS SYSTEMS AND MANAGEMENT	5
JOURNAL OF AGRICULTURAL ECONOMICS	5
PROGRESS IN INDUSTRIAL ECOLOGY	5
PULP AND PAPER CANADA	5
RENEWABLE ENERGY: FOUR VOLUME SET	5
RESOURCE AND ENERGY ECONOMICS	5
SUSTAINABILITY ACCOUNTING, MANAGEMENT AND POLICY JOURNAL	5
THE BIOBASED ECONOMY: BIOFUELS, MATERIALS AND CHEMICALS IN THE POST-OIL ERA	5
BIO-BASED AND APPLIED ECONOMICS	4
BUSINESS STRATEGY AND THE ENVIRONMENT	4
GERMAN JOURNAL OF AGRICULTURAL ECONOMICS	4
INTERNATIONAL ECONOMICS	4
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ENGINEERING AND TECHNOLOGY	4
JOURNAL OF ENVIRONMENTAL MANAGEMENT AND TOURISM	4
JOURNAL OF POLICY MODELING	4
LAND ECONOMICS	4
PAPER360	4
PPI PULP AND PAPER INTERNATIONAL	4
QUALITY - ACCESS TO SUCCESS	4
SCIENCE AND ENGINEERING ETHICS	4
WORLD TRADE REVIEW	4
ACTUAL PROBLEMS OF ECONOMICS	3
AGRIBUSINESS	3
AGRICULTURAL AND RESOURCE ECONOMICS REVIEW	3
AGRIS ONLINE PAPERS IN ECONOMICS AND INFORMATICS	3
BIOREFINERY: INTEGRATED SUSTAINABLE PROCESSES FOR BIOMASS CONVERSION TO BIOMATERIALS, BIOFUELS, AND FERTILISERS	3
ECONOMIC AND POLITICAL WEEKLY	3
INTERNATIONAL FOOD AND AGRIBUSINESS MANAGEMENT REVIEW	3
INTERNATIONAL JOURNAL OF AUTOMOTIVE TECHNOLOGY AND MANAGEMENT	3
INTERNATIONAL JOURNAL OF ENERGY SECTOR MANAGEMENT	3
INTERNATIONAL JOURNAL OF INDUSTRIAL ENGINEERING AND PRODUCTION RESEARCH	3
INTERNATIONAL JOURNAL OF INNOVATION AND SUSTAINABLE DEVELOPMENT	3
INTERNATIONAL JOURNAL OF PRECISION ENGINEERING AND MANUFACTURING - GREEN TECHNOLOGY	3
INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	3
JOURNAL OF AIR TRANSPORT MANAGEMENT	3
JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT	3
JOURNAL OF TECHNOLOGY MANAGEMENT AND INNOVATION	3
NEW MEDIT	3
OPEC BULLETIN	3
PULP AND PAPER	3
TECHNOLOGY ANALYSIS AND STRATEGIC MANAGEMENT	3
TRANSPORT ENGINEER	3

Table 7
Extension of Table 6

Author(s), Year	DOI	TC	TCY	NTC
SHRIVASTAV A, 2010, INT J BIOL MACROMOL	10.1016/j.ijbiomac.2010.04.007	98	7.00	3.42
UDAY USP, 2016, INT J BIOL MACROMOL	10.1016/j.ijbiomac.2015.10.086	98	12.25	5.85
DE GORTER H, 2009, AM J AGRIC ECON-a	10.1111/j.1467–8276.2008.01190.x	98	6.53	3.00
PALAK G, 2014, INT J PROD ECON	10.1016/j.ijpe.2014.04.019	97	9.70	3.37
MURPHY R, 2011, FOOD POLICY	10.1016/j.foodpol.2010.11.014	96	7.38	5.38
REIJNDERS L, 2008, J CLEAN PROD	10.1016/j.jclepro.2008.01.012	95	5.94	9.92
BABAZADEH R, 2017, J CLEAN PROD	10.1016/j.jclepro.2015.09.038	94	13.43	3.64
FATTAHI M, 2018, TRANSP RES PART E LOGIST TRANSP REV	10.1016/j.tre.2018.08.008	94	15.67	4.23
BAI Y, 2012, ENERGY ECON	10.1016/j.eneco.2012.01.003	94	7.83	3.02
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NABI MN, 2017, J CLEAN PROD	10.1016/j.jclepro.2017.08.096	87	12.43	3.37
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AHMED S, 2014, J CLEAN PROD	10.1016/j.jclepro.2014.05.019	84	8.40	2.92
DARDA S, 2019, J CLEAN PROD	10.1016/j.jclepro.2018.10.147	82	16.40	4.41
LANI NS, 2017, J CLEAN PROD	10.1016/j.jclepro.2016.06.058	81	11.57	3.13
PUTRA MD, 2018, J CLEAN PROD	10.1016/j.jclepro.2018.06.010	80	13.33	3.60
HOSSAIN N, 2020, J CLEAN PROD	10.1016/j.jclepro.2020.120261	80	20.00	4.70
LIANG H, 2016, J CLEAN PROD	10.1016/j.jclepro.2016.04.151	80	10.00	4.77
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NATH B, 2019, J CLEAN PROD	10.1016/j.jclepro.2019.118112	76	15.20	4.09
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PATEL A, 2017, J CLEAN PROD	10.1016/j.jclepro.2016.10.184	75	10.71	2.90
ZHANG X, 2014, FRONT ENERGY RES	10.3389/fenrg.2014.00032	75	7.50	2.60
SEGUÍ L, 2018, J CLEAN PROD	10.1016/j.jclepro.2017.10.284	74	12.33	3.33
REYIMU Z, 2017, J CLEAN PROD	10.1016/j.jclepro.2017.02.189	74	10.57	2.86
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WRIGHT B, 2014, J ECON PERSPECT	10.1257/jep.28.1.73	72	7.20	2.50
MARUFUZZAMAN M, 2014, TRANSP RES PART E LOGIST TRANSP REV	10.1016/j.tre.2014.06.008	72	7.20	2.50
IGLESIAS L, 2012, J CLEAN PROD	10.1016/j.jclepro.2012.07.002	71	5.92	2.28
VACHA L, 2013, ENERGY ECON	10.1016/j.eneco.2013.06.015	71	6.45	3.14
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Notes: Authors' analysis [TC = Total Citation, TCY = Total Citation per Year, NTC = Normalized Total Citation].

Table 8
Thematic evaluation

From	To	Words	WII	II	O	SI
biodiesel–1998-2016	biodiesel–2017-2022	biodiesel; microalgae; alternative fuel; optimization	0.56	0.05	120	0.01
biodiesel–1998-2016	bioethanol–2017-2022	bioethanol; environmental impacts; life cycle analysis; lignin	0.16	0.05	25	0.02
biodiesel–1998-2016	biofuels–2017-2022	life cycle assessment; renewable energy; supply chain; ghg emissions; system dynamics; emission reduction	0.17	0.05	15	0.01
biofuel policy–1998-2016	biodiesel–2017-2022	biofuel policy	0.09	0.1	7	0.01
biofuel policy–1998-2016	biofuels–2017-2022	european union; trade; transport	0.2	0.1	5	0.01
biofuel production–1998-2016	biofuels–2017-2022	biofuel production	0.2	0.2	5	0.01
biofuels–1998-2016	bioethanol–2017-2022	lca; algae; carbon footprint; corn stover	0.07	0.03	11	0.01
biofuels–1998-2016	biofuels–2017-2022	biofuels; biofuel; sustainability; ethanol; biomass; bioenergy; climate change; land use; land use change; sustainable development; biogas; biorefinery	0.6	0.03	148	0.01
biofuels–1998-2016	crude oil–2017-2022	crude oil	1	1	4	0.03
brazil–1998-2016	biofuels–2017-2022	brazil; innovation; patents	0.24	0.13	10	0.01
energy–1998-2016	biofuels–2017-2022	energy; environment; agriculture; greenhouse gases	0.45	0.14	13	0.01
engine performance–1998-2016	biodiesel–2017-2022	engine performance	0.63	0.5	5	0.01
food security–1998-2016	biofuels–2017-2022	food security	0.2	0.33	8	0.01
	biofuels–2017-2022	greenhouse gas emissions; energy policy	0.11	0.09	22	0.01

(continued on next page)

Table 8 (*continued*)

From	To	Words	WII	II	O	SI
greenhouse gas emissions–1998-2016						
greenhouse gas emissions–1998-2016	renewable fuel standard–2017-2022	biofuel policies; renewable fuel standard	1	0.5	11	0.08
jatropha–1998-2016	biodiesel–2017-2022	palm oil	0.36	0.33	4	0.01
jatropha–1998-2016	biofuels–2017-2022	jatropha	0.36	0.33	4	0.01
life cycle assessment (lca)–1998-2016	biodiesel–2017-2022	life cycle assessment (lca)	0.33	0.5	6	0.01
uncertainty–1998-2016	biofuels–2017-2022	uncertainty	0.57	0.5	4	0.01
waste cooking oil–1998-2016	biodiesel–2017-2022	waste cooking oil; transesterification; biodiesel production; emission; esterification; performance	1	0.17	8	0.01

Notes: WII = Weighted Inclusion Index; II = Inclusion Index; O = Occurrences; SI = Stability Index.

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