



Mapping biofuel field: A bibliometric evaluation of research output



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ABSTRACT

Among sustainable and renewable energies, biofuels appear to be the most promising and attractive, and related research has been expanding along with an exceptional growth of scientific knowledge. Based on the Science Citation Index Expanded from the Web of Science, a bibliometric evaluation of research output was carried out to map research activities and tendencies of the global biofuel field. The results indicate that annual output of scientific articles rocketed during the past decade (2003–2012). The United States of America (USA) is leading biofuels research and collaborated mainly with other productive countries (China, United Kingdom, Germany, Canada and South Korea). In general, international collaborative publications resulted in more citations than single country publications. Institutional collaborations became increasingly prevalent over time and the 15 most productive institutions of USA tended to collaborate more with each other. Most research publications on biofuels appeared in the journals *Biomass and Bioenergy* and *Bioresource Technology*. Furthermore, biofuels research was based on combinations of multi-subject categories including “Energy and fuels”, “Biotechnology and applied microbiology”, “Chemical engineering”, “Environmental sciences” and “Agricultural engineering”. The keyword analysis confirmed the production of biodiesel from microalgae as the mainstream of recent biofuels research. Biorefinery was the most common technology for conversions of biological feedstock and life cycle assessment was the most popular tool of decision support to evaluate the sustainability of biofuel development.

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1. Introduction

Mitigation of changing climate and meeting increasing energy needs are quickly becoming two of the most important challenges all over the world in this 21st century [1]. It has been commonly recognized by governments, commercial organizations and academic

communities that the only way to face these two global challenges is to develop economically rational, environmentally friendly, sustainable and renewable energy [2]. Among various alternatives, biomass-derived fuel appears to be the most promising and attractive, and it is expected to grow in the foreseeable future [3]. Government responses to those global concerns include policies which promote the production and use of biofuels. Such policies have been established by more than 35 countries including the United States of America (USA), members of European Union, China and Brazil [4]. The ambitious goal from USA Department of Energy is to derive 20% of the transportation fuel from biomass by 2030 [5]. With incentives

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from governmental policies and commercial benefits, new companies with great enthusiasm for biofuel have sprung up almost overnight and most of major oil companies (e.g. ExxonMobil and Chevron) are also researching and investing in biomass-derived fuel [6]. Many important and challenging research areas have the potential to bring significant positive outcomes for our future needs of sustainable energy [7]. Thus, a thorough review of the science behind biofuels is urgently needed to improve our understanding of biomass-derived fuel.

Considering that many studies of biofuel have already been published, a bibliometric evaluation of publications could serve as an alternative and innovative way of connecting various aspects of scientific finding and revealing global trends of biofuel research. Bibliometric studies are based on the research methodology employed in the science of library and information, and it includes a series of quantitative and visual procedures to generalize the patterns and dynamics of publications [8]. The focus of specific research fields could be reflected by the publication of scientific findings which is a critical part of the research process [9]. Bibliometric methods have already been widely performed in many disciplines of science and engineering, and could be considered as a common research tool to interpret the scientific production and research trends of a specific topic [10,11]. One of the major sources for bibliometric information is the Web of Science database (Institute for scientific information, ISI), and more than 10,000 high-impact journals are indexed in this multidisciplinary database of sciences, social sciences, arts and humanities [12]. Based on publication outputs by countries, institutes, journals and research fields, the temporal bibliometric analysis aims to analyze the development of research fields across different periods [13]. While the conventional bibliometric analysis centers around numbers and citations of articles, some of the newly-developed bibliometric methods aim to display the intellectual connections of changing scientific knowledge or the structural and dynamic aspects of scientific research as well [14]. Furthermore, geographic analyses can elucidate spatial pattern and identify geographic areas in which most of the research activity occurs [15]. Network analysis allows us to understand the

interrelationships among research disciplines, helps us to visualize the collaborative patterns among countries and institutions, and can identify the hot issues of a research field [16].

Based on the ISI web of Science information during the period of 1979–2012, the present bibliometric evaluation combined traditional and innovative methods to examine the temporal, spatial, structural and current aspects of biofuel research. More specifically, the present article involves in the following four aspects: (1) Analysis of temporal trends of annual outputs and performances of biofuel research, using numbers of publications, authors, pages, citations and references as response variables; (2) Geographic analysis of contact addresses to display the global distribution of biofuel research and focus on outputs and performances of the 20 most productive countries and institutions. The geographic analysis was combined with a network analysis to show collaborative patterns among countries and institutions at international and inter-institutional scales; (3) Ranking of most commonly cited journals by outputs and performances of publications. Network and temporal analysis helped to visualize the connections of multidisciplinary research and dynamics of core scientific categories; (4) Extraction of the most frequent keywords to demonstrate the evolution of research focus. A co-words network of the 50 most frequently used keywords was formed to identify the hot issues of biofuel research. This article will provide additional insights into the current hotspots and future projections of biofuel research.

2. Data and methods

The bibliometric information of biofuel publications was downloaded from the Scientific Citation Index (SCI) databases of the web of Science (Thomson Reuters) which is maintained by the Institute of Scientific Information (USA). We searched for “biofuel” among documents published between 1900 and 2012, but the earliest publication related to this topic was indexed by the SCI database in 1976. The downloaded record of individual document included the following fields: Authors (AU), Document Title (TI), Language (LA), Document Type (DT), Author Keywords (DE), Keywords plus (ID), Author Address (C1), Reference count (NR), Times

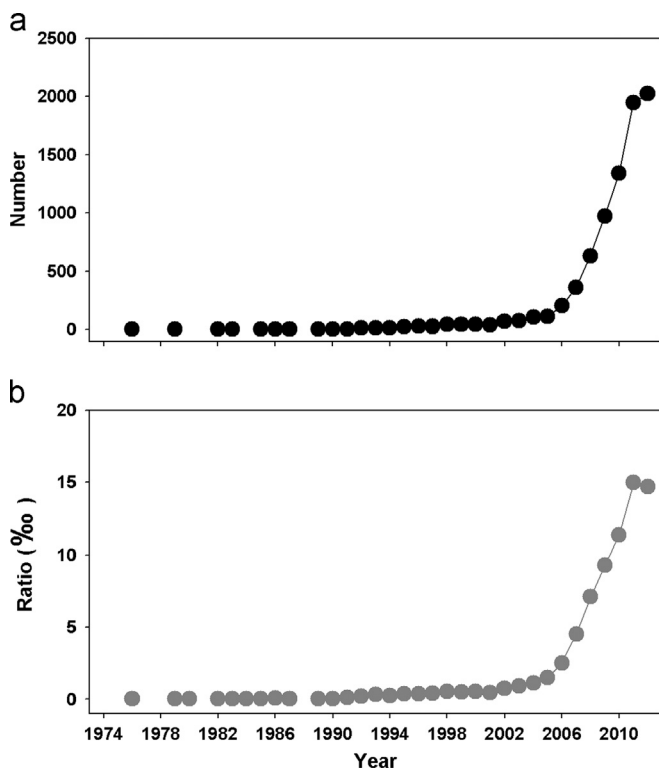


Fig. 1. The dynamics of total research articles (a) and standardized index (b).

Table 1
Characteristics of publications outputs from 1991 to 2012.

Year	TP	PG	PG/TP	TC	TC/TP	AU	AU/TP	NR	NR/TP
1991	4	60	15.0	54	13.5	7	1.8	74	18.5
1992	14	200	14.3	148	10.6	31	2.2	386	27.6
1993	13	82	6.3	109	8.4	36	2.8	101	7.8
1994	12	139	11.6	113	9.4	42	3.5	130	10.8
1995	23	189	8.2	709	30.8	63	2.7	376	16.3
1996	27	284	10.5	782	29.0	85	3.1	590	21.9
1997	26	260	10.0	991	38.1	68	2.6	669	25.7
1998	45	458	10.2	1287	28.6	115	2.6	1317	29.3
1999	44	413	9.4	1626	37.0	112	2.5	1033	23.5
2000	46	479	10.4	1832	39.8	166	3.6	1220	26.5
2001	39	424	10.9	1950	50.0	186	4.8	1235	31.7
2002	69	613	8.9	2802	40.6	228	3.3	1777	25.8
2003	76	942	12.4	4025	53.0	354	4.7	2306	30.3
2004	106	1036	9.8	5463	51.5	440	4.2	3357	31.7
2005	114	1070	9.4	4329	38.0	418	3.7	3767	33.0
2006	204	1637	8.0	7868	38.6	692	3.4	5473	26.8
2007	361	3019	8.4	9400	26.0	1,259	3.5	10,563	29.3
2008	632	5779	9.1	16,601	26.3	2,446	3.9	21,264	33.6
2009	974	8966	9.2	14,173	14.6	3,905	4.0	34,502	35.4
2010	1342	13,084	9.7	13,489	10.1	5,684	4.2	53,485	39.9
2011	1946	18,789	9.7	9890	5.1	8,480	4.4	77,818	40.0
2012	2024	19,484	9.6	1796	0.9	9,441	4.7	84,011	41.5
Average			10.0		27.3		3.5		27.6

TP=number of publications, PG=Page count, TC=Times Cited, AU=number of Authors and NR=Reference count; PG/TP, TC/TP, AU/TP and NR/TP are average numbers of pages, citations, authors and references per article, respectively.

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