Bibliometric analysis of international cooperation in biomass energy research

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It is well known that biomass energy has excellent environmental and economic benefits. The increasing international cooperation in the field of biomass energy has promoted the rapid coordinated development of global biomass energy research and industry. This article analyses academic papers in this field collected by SSCI or SCI from 2007 to 2016, uses bibliometrics for quantitative statistics and data mining, and VOSviewer software to generate international cooperation network maps. It also provides in-depth analysis and comprehensive comparison of changes in international cooperation in biomass energy research in major countries around the world, and reveals the context and direction of development in the global biomass energy field. The results of this study can provide scientific basis and support for the development of other related research work.

Keywords: Biomass energy, bibliometrics, data mining, international collaboration.

BIOMASS energy plays an important role in responding to global climate change, energy supply and demand contradiction, and protecting the ecological environment[1]. It is the world's fourth largest energy source after oil, coal and natural gas, and has become an important force in the international energy transformation. At present, many countries not only formulate policies and measures to promote the development of biomass energy, but also set development goals and plans[2]. The development and utilization of biomass energy has attracted extensive attention from governments and scientists in various countries.

International scientific and technological cooperation has become an important model for the development of scientific research. Making full use of the world's advanced scientific and technological resources to develop and strengthen international cooperation has become an important part of scientific research, and has promoted the progress and innovation of science and technology (S&T). Energy and the environment are the main concerns of countries around the world. Research on biomass energy is the hot topic around the world. With the gradual deepening of research on biomass energy, breakthrough achievements have been made in the field. However, it is necessary to point out that international cooperation plays a key role that cannot be ignored.

Bibliometrics refers to the use of mathematical and statistical methods to quantitatively analyse the cross-science of all knowledge carriers[3–6]. It is a comprehensive knowledge system that integrates mathematics, statistics and philology as a whole, and focuses on quantification[7–9]. Bibliometric methods are widely used in many areas, including medical science[10], environmental science[11], management[12], business[13] and computer science[14].

Bibliometrics is also common in research through international cooperation. Some scholars analysed different issues, including the structure of international cooperation networks, cooperation models, cooperation intensity and the trend of their changes. Glänzel *et al.*[15] performed a bibliometric analysis of scientific cooperation of the European Union countries with other highly industrialized countries and less advanced countries. Based on the bibliometric analysis of the top journals in the energy area, Duan[16] found that most critical partner countries for China are USA, some European countries and Japan. With more than 100,000 papers as research samples, Li and Zhao[17] studied the issues of international cooperation in the field of environmental assessment. By using network centralities, they effectively identified the core countries in the international cooperation network in this field. Merigó *et al.*[18] studied the structure, patterns, and maps of international cooperation networks in the field of innovation. De Paulo and Porto[19] examined international cooperation in the field of solar energy technologies. Bibliometric and social network analysis methods were used to explore the national and international partnerships. They indicated that international cooperation in the field of solar energy technology is common in some developed countries like the Netherlands, Germany and United Kingdom. But so far bibliometrics has not been used in international cooperation studies in the field of biomass energy, which is the focus of the present study. It deals with two aspects of the basic situation of international

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cooperation and international cooperation network in the field of biomass energy.

Data and methods

ISI Web of Science is the largest and most comprehensive academic information resource in the world[20,21]. It integrates Science Citation Index Expanded (SCIE), Social Science Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), and the original conference proceedings database on the Web of Knowledge platform. Based on the research scope of biomass energy, this study adopts the topic retrieval method to search the biomass energy research literature from 2007 to 2016 with 'biomass OR biofuel OR biodiesel OR bioethanol OR biomass power or biogas'[22]. The retrieval time is 12 April 2017. The literature types are limited to research articles and review, and a total of 172,029 original article records were obtained.

Essential Science Indicators (ESI) is a literature review analysis tool introduced by ISI in 2001 (refs 22–24). This is an econometric analysis database established based on more than 10 million document records collected by SCI and SSCI from over 11,000 academic journals worldwide. Through this database, users can understand the leading countries, journals, scientists, papers and research institutions in each field of research, and identify important trends and directions in various fields[25–27]. The present study collected all ESI papers in the field of biomass energy to examine international cooperation issues in the field. On 12 April 2017, 3185 ESI papers in the field of biomass energy were retrieved. The main purpose of this study to reveal the international cooperation in the field of biomass energy. VOSviewer is a software tool for constructing and visualizing bibliometric networks[28–30]. This was used for mapping the international cooperation network in the field of biomass energy.

Results

With the globalization of S&T, international cooperation has become an indispensable and important component in this field. As an important measure of optimal allocation of resources in national S&T development strategy, international cooperation plays an important supporting role in enhancing national independent innovation capability. Using the personalized data mining method, this study systematically analyses the papers through international cooperation in the field of biomass energy, reveals the modes and characteristics of international cooperation in the field, and describes the status and role of the countries in the cooperative network.

Table 1 lists the number of papers through independent research and international cooperation among the top 20 countries during 2007–2016 in the field of biomass energy. With the rapid development of this field, the absolute number of publications of various countries in Table 1, whether through independent research or international cooperation, is growing. For example, the number of papers through international cooperation in USA increased from 9775 during 2007–2011 to 13,811 during 2012–2016, while the number of independent research papers increased from 4408 to 9591 in the same period.

According to the share of international cooperation and independent research, the former has become the main research model of Germany and the UK during 2012–2016. The number of papers through international cooperation of these two countries far exceeds the results of independent research publications. In this period, in addition to Germany and the UK, countries with a higher proportion of international cooperation include Canada, France, Australia, the Netherlands, Sweden, Denmark and Finland.

Comparing the changes in the share of international cooperation and independent research between the two periods, it can be found that the vast majority of countries have increased their share of international cooperation. This indicates that most countries have given international cooperation research more attention. However, the international cooperation share of China and South Korea has shown a downward trend. For example, China's international cooperation share has dropped from 69.00% to 30.41%, and South Korea's share dropped from 37.93% to 34.71%.

Table 2 provides details on international cooperation and independent research of ESI publications in the field of biomass energy. The conclusions are similar to those in Table 1. But it is clear that, for the vast majority of countries, the international cooperation rate shown in Table 2 is significantly higher than that in Table 1. This shows that international cooperation is more conducive to yielding high-impact research results in the field of biomass energy.

At present, international scientific and technological cooperation has gradually become an inevitable choice for scientific research[31]. It is of great significance to analyse the characteristics of international cooperation between different countries in the field of biomass energy. Table 3 provides the details of the five countries with the most cooperation among the top 20 countries (according to the international cooperation publication number).

During the period 2007–2016, the country with the largest number of papers co-authored with USA was China, with a total of 3639 publications. This was followed by Canada, the UK, Germany, and Australia. As can be seen from Table 3, USA is the world's major partner in international cooperation in the field of biomass energy. This indicates that these countries played an important role in building a strong international cooperation network. Table 4 provides information on the most popular partner of ESI publications in the field of biomass energy. We studied the co-authorship of ESI publications

Table 1. Distribution of papers through independent research and international cooperation

Country/region	TP	2007–11				2012–16				Change in independent research	Change in international cooperation
		Independent research		International cooperation		Independent research		International cooperation			
		$TP_{07–11}$	Percentage	$TP_{07–11}$	Percentage	$TP_{12–16}$	Percentage	$TP_{12–16}$	Percentage		
USA	38,781	9,775	65.10	4,408	29.36	13,811	58.11	9,591	40.36	–6.99	11.00
China	27,945	2,180	30.76	4,890	69.00	14,517	69.60	6,342	30.41	38.84	–38.59
Germany	10,461	1,029	26.98	2,760	72.36	1,509	22.70	5,106	76.82	–4.28	4.45
India	10,402	2,875	82.81	584	16.82	5,452	78.67	1,468	21.18	–4.13	4.36
UK	9,971	1,122	28.88	2,341	60.26	1,606	26.39	4,345	71.39	–2.49	11.14
Brazil	9,546	2,426	75.67	773	24.11	4,449	70.17	1,875	29.57	–5.50	5.46
Spain	8,733	1,962	61.91	1,198	37.80	2,869	51.56	2,687	48.29	–10.35	10.49
Canada	8,299	1,855	58.01	1,331	41.62	2,517	49.34	2,570	50.38	–8.66	8.76
France	7,414	1,106	40.03	1,466	53.06	1,681	36.14	2,913	62.63	–3.89	9.57
Australia	6,863	1,206	51.74	1,105	47.40	1,870	41.26	2,642	58.30	–10.48	10.89
Japan	6,631	1,746	66.09	889	33.65	2,229	55.88	1,754	43.97	–10.21	10.32
Italy	6,270	1,298	62.13	789	37.77	2,282	54.58	1,894	45.30	–7.55	7.53
The Netherlands	4,534	758	43.41	981	56.19	889	31.89	1,887	67.68	–11.53	11.50
South Korea	4,472	765	61.99	468	37.93	2,110	65.16	1,124	34.71	3.17	-3.21
Sweden	4,341	734	46.96	821	52.53	1,095	39.42	1,670	60.12	–7.54	7.59
Poland	3,193	791	77.47	201	19.69	1,704	78.45	468	21.55	0.98	1.86
Turkey	3,127	1,192	83.18	238	16.61	1,194	70.48	498	29.40	–12.70	12.79
Malaysia	2,986	444	64.82	241	35.18	1,257	54.63	1,042	45.28	–10.19	10.10
Denmark	2,899	447	43.36	576	55.87	649	34.74	1,212	64.88	–8.61	9.01
Finland	2,674	493	55.39	395	44.38	798	44.73	981	54.99	–10.66	10.61

Table 2. Independent research and international cooperation of the ESI publications

Country/region	TP	2007–11				2012–16				Change in independent research	Change in international cooperation
		Independent research		International cooperation		Independent research		International cooperation			
		$TP_{07–11}$	Percentage	$TP_{07–11}$	Percentage	$TP_{12–16}$	Percentage	$TP_{12–16}$	Percentage		
USA	1,161	333	60.00	222	40.00	277	45.79	328	54.21	–14.21	14.21
China	473	70	46.98	79	53.02	153	49.51	156	50.49	2.53	–2.53
UK	455	33	82.50	7	17.50	27	6.96	361	93.04	–75.54	75.54
Germany	306	44	32.59	91	67.41	34	19.88	137	80.12	–12.71	12.71
Australia	221	25	35.71	45	64.29	40	26.49	111	73.51	–9.22	9.22
France	212	21	27.27	56	72.73	24	17.78	111	82.22	–9.49	9.49
India	206	71	70.30	30	29.70	53	50.48	52	49.52	–19.82	19.82
Canada	202	29	33.33	58	66.67	40	34.78	75	65.22	1.45	–1.45
Spain	198	35	43.21	46	56.79	38	32.48	79	67.52	–10.73	10.73
The Netherlands	173	29	42.65	39	57.35	13	12.38	92	87.62	–30.27	30.27
Italy	148	15	27.78	39	72.22	22	23.40	72	76.60	–4.37	4.37
Sweden	117	8	18.18	36	81.82	10	13.70	63	86.30	–4.48	4.48
Malaysia	112	24	68.57	11	31.43	45	58.44	32	41.56	–10.13	10.13
Switzerland	108	8	18.60	35	81.40	8	12.31	57	87.69	–6.30	6.30
Denmark	104	13	32.50	27	67.50	14	21.88	50	78.13	–10.63	10.63
Japan	101	12	30.77	27	69.23	19	30.65	43	69.35	–0.12	0.12
Turkey	92	68	93.15	5	6.85	12	63.16	7	36.84	–29.99	29.99
Belgium	89	8	24.24	25	75.76	13	23.21	43	76.79	–1.03	1.03
Brazil	86	7	23.33	23	76.67	9	16.07	47	83.93	–7.26	7.26
Austria	83	4	11.76	30	88.24	8	16.33	41	83.67	4.56	–4.56

Table 3. Five countries with the most cooperation among the top 20 countries

Country/region	Cooperation number	Partners														
		First			Second			Third			Fourth			Fifth		
		TP1	Percentage	Country 1	TP2	Percentage	Country 2	TP3	Percentage	Country 3	TP4	Percentage	Country 4	TP5	Percentage	Country 5
USA	13,999	3,639	25.99	China	1,647	11.77	Canada	1,628	11.63	UK	1,140	8.14	Germany	1,050	7.50	Australia
China	11,232	3,639	32.40	USA	860	7.66	Australia	726	6.46	Canada	709	6.31	Japan	677	6.03	UK
Germany	7,866	1,140	14.49	USA	915	11.63	UK	655	8.33	France	602	7.65	China	545	6.93	The Netherlands
UK	6,686	1,448	21.66	USA	814	12.17	Germany	648	9.69	China	614	9.18	France	574	8.59	Australia
France	4,379	857	19.57	USA	709	16.19	UK	655	14.96	Germany	475	10.85	Spain	415	9.48	Canada
Canada	3,901	1,647	42.22	USA	726	18.61	China	443	11.36	UK	415	10.64	France	333	8.54	Germany
Spain	3,885	686	17.66	USA	619	15.93	UK	475	12.23	France	419	10.79	Germany	406	10.45	Italy
Australia	3,747	1,050	28.02	USA	860	22.95	China	671	17.91	UK	326	8.70	Germany	261	6.97	France
The Netherlands	2,868	583	20.33	UK	578	20.15	USA	545	19.00	Germany	295	10.29	France	294	10.25	Belgium
Italy	2,683	510	19.01	USA	510	19.01	UK	406	15.13	Spain	401	14.95	Germany	396	14.76	France
Brazil	2,648	927	35.01	USA	356	13.44	UK	273	10.31	France	268	10.12	Germany	235	8.87	Spain
Japan	2,643	709	26.83	China	523	19.79	USA	223	8.44	Thailand	196	7.42	South Korea	182	6.89	Malaysia
Sweden	2,491	465	18.67	USA	418	16.78	UK	366	14.69	Germany	311	12.48	Finland	298	11.96	Denmark
India	2,052	547	26.66	USA	271	13.21	South Korea	173	8.43	UK	155	7.55	Australia	146	7.12	Canada
Denmark	1,788	358	20.02	USA	298	16.67	Sweden	287	16.05	UK	278	15.55	Germany	239	13.37	China
South Korea	1,592	619	38.88	USA	271	17.02	India	196	12.31	Japan	192	12.06	China	67	4.21	Pakistan
Finland	1,376	311	22.60	Sweden	260	18.90	USA	214	15.55	UK	205	14.90	Germany	139	10.10	The Netherlands
Malaysia	1,283	182	14.19	Japan	147	11.46	UK	136	10.60	Australia	101	7.87	Indonesia	99	7.72	USA
Turkey	736	157	21.33	USA	67	9.10	Germany	53	7.20	UK	44	5.98	Italy	41	5.57	Canada
Poland	669	120	17.94	Germany	102	15.25	USA	84	12.56	UK	83	12.41	France	56	8.37	Italy

Table 4. Five countries with the most cooperation among the top 20 countries for ESI publications

		Partners													
		First			Second			Third			Fourth			Fifth		
Country/region	Cooperation number	TP1	Percentage	Country 1	TP2	Percentage	Country 2	TP3	Percentage	Country 3	TP4	Percentage	Country 4	TP5	Percentage	Country 5
USA	550	170	30.91	UK	117	21.27	China	108	19.64	Germany	87	15.82	Australia	85	15.45	Canada
UK	368	148	40.22	USA	81	22.01	Germany	79	21.47	France	59	16.03	The Netherlands	57	15.49	Australia
China	235	117	49.79	USA	45	19.15	UK	38	16.17	Germany	35	14.89	Australia	24	10.21	Canada
Germany	228	108	47.37	USA	97	42.54	UK	60	26.32	France	51	22.37	The Netherlands	40	17.54	Switzerland
France	167	103	61.68	UK	80	47.9	USA	60	35.93	Germany	41	24.55	Italy	40	23.95	The Netherlands
Australia	156	87	55.77	USA	45	28.85	UK	35	22.44	China	29	18.59	Germany	28	17.95	France
Canada	133	85	63.91	USA	49	36.84	UK	32	24.06	Germany	29	21.8	France	24	18.05	China
The Netherlands	131	75	57.25	UK	69	52.67	USA	51	38.93	Germany	40	30.53	France	27	20.61	Italy
Spain	125	60	48.00	UK	58	46.40	USA	27	21.60	France	26	20.80	Italy	26	20.80	Germany
Italy	111	55	49.55	UK	53	47.75	USA	41	36.94	France	34	30.63	Germany	27	24.32	The Netherlands
Sweden	99	55	55.56	UK	43	43.43	USA	28	28.28	Germany	24	24.24	Denmark	21	21.21	France
Switzerland	92	55	59.78	USA	47	51.09	UK	40	43.48	Germany	30	32.61	France	21	22.83	The Netherlands
India	82	32	39.02	USA	15	18.29	UK	12	14.63	Australia	10	12.2	China	10	12.2	Canada
Denmark	77	39	50.65	UK	31	40.26	USA	25	32.47	Germany	24	31.17	Sweden	24	31.17	The Netherlands
Austria	71	38	53.52	USA	37	52.11	Germany	29	40.85	UK	19	26.76	Italy	19	26.76	France
Japan	70	37	52.86	USA	30	42.86	UK	22	31.43	Germany	22	31.43	France	17	24.29	China
Brazil	70	52	74.29	USA	50	71.43	UK	20	28.57	The Netherlands	19	27.14	Germany	19	27.14	Australia
Belgium	68	35	51.47	USA	31	45.59	UK	19	27.94	The Netherlands	18	26.47	Italy	18	26.47	France
Malaysia	43	11	25.58	Indonesia	8	18.6	USA	7	16.28	Australia	7	16.28	UK	5	11.63	Japan
Turkey	12	3	25	Italy	3	25	Greece	3	25	Germany	3	25	Canada	2	16.67	USA

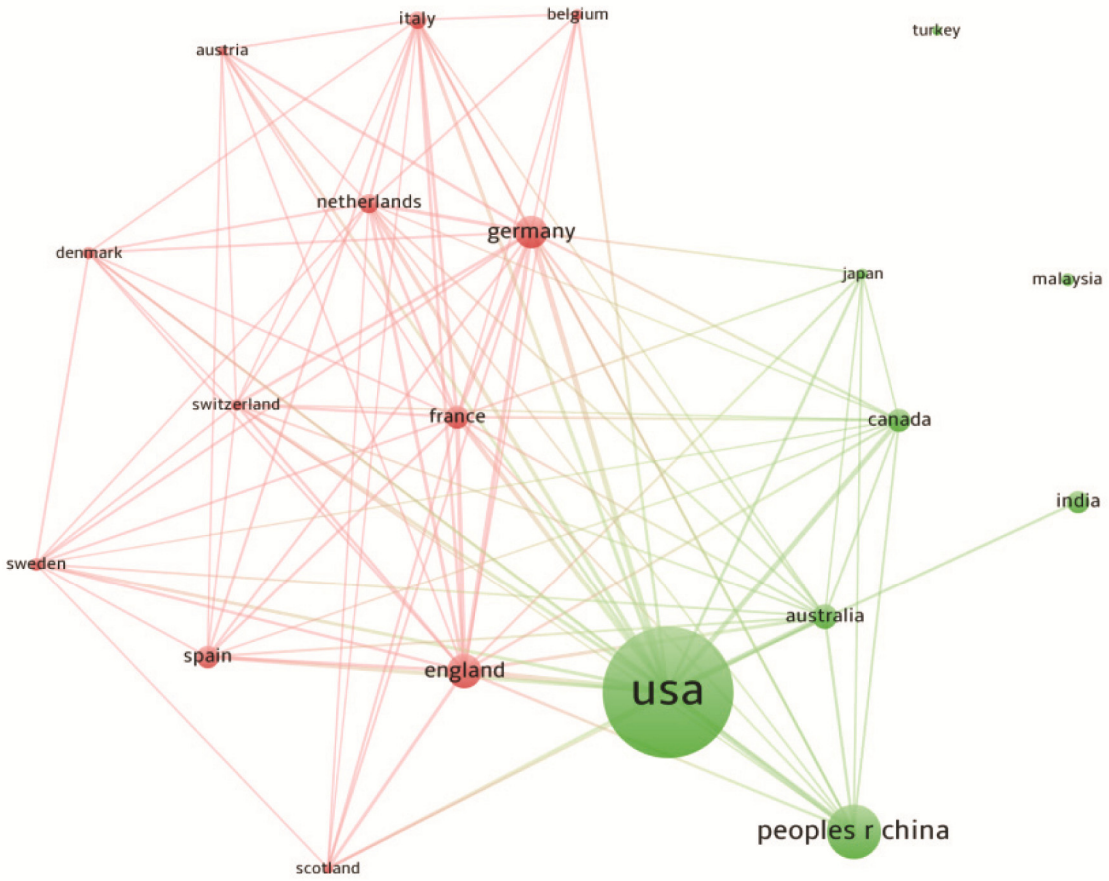

Figure 1. Co-authorship of the top 20 countries.

in the field of biomass energy. Figure 1 presents the co-authorship of the top 20 countries.

Conclusion

Through a literature review of relevant international biomass energy research papers, the international cooperation from 2007 to 2016 has been revealed from a quantitative and qualitative perspective. The analysis results are as follows:

(1) In the field of biomass energy, the number of research papers has grown rapidly, indicating that researchers are paying more attention to this field. (2) The main countries for biomass energy research are USA, China, Germany, India and the UK. Among them, USA ranks first in the field in absolute research, and China ranks second, but China's research literature in this field has grown the fastest, indicating that it has considerable potential in research in this field. (3) The country with the largest number of papers co-authored with USA is China, followed by Canada, the UK, Germany and Australia. USA is the world's major partners in international cooperation, and it has become the leading force in international cooperation in the field of biomass energy. (4) The vast majority of countries have increased their share of international cooperation. International cooperation is more conducive to yielding high-impact research results in the field of biomass energy.

In summary, international biomass energy research has developed rapidly and international cooperation has become an important method for research in this field. Actively attracting international innovation forces and resources, and strengthening cooperation with the developed countries can further enhance the academic influence of research in the field of biomass energy.

1. Herbert, G. J. and Krishnan, A. U., Quantifying environmental performance of biomass energy. *Renew. Sust. Energ. Rev.*, 2016, **59**, 292–308.
2. Yu, D. J. and Xu, C., Mapping research on carbon emissions trading: a co-citation analysis. *Renew. Sust. Energ. Rev.*, 2017, **74**, 1314–1322.
3. Elango, B. and Ho, Y. S., A bibliometric analysis of highly cited papers from India in Science Citation Index Expanded. *Curr. Sci.*, 2017, **112**(8), 1653–1658.
4. Merigó, J. M. and Yang, J. B., A bibliometric analysis of operations research and management science. *Omega*, 2017, **73**, 37–48.

5. Yu, D. J., Xu, Z. S. and Wang, W. R., Bibliometric analysis of fuzzy theory research in China: A 30-year perspective. *Knowl.-Based Syst.*, 2018, **141**, 188–199.
6. Yu, D. J., Xu, Z. S. and Fujita, H., Bibliometric analysis on the evolution of applied intelligence. *Appl. Intell.*, 2019, **49**(2), 449–462.
7. Laengle, S. *et al.*, Forty years of the *European Journal of Operational Research*: a bibliometric overview. *Eur. J. Oper. Res.*, 2017, **262**(3), 803–816.
8. Yu, D. J., Wang, W. R., Zhang, S., Zhang, W. Y. and Liu, R. Y., A multiple-link, mutually reinforced journal-ranking model to measure the prestige of journals. *Scientometrics*, 2017, **111**(1), 521–542.
9. Wang, P., Zhu, F., Song, H. and Hou, J., A bibliometric profile of *Current Science* between 1961 and 2015. *Curr. Sci.*, 2017, **113**(3), 386–392.
10. Takahashi, R. and Kajikawa, Y., Computer-aided diagnosis: a survey with bibliometric analysis. *Int. J. Med. Informat.*, 2017, **101**, 58–67.
11. Zhang, S., Mao, G., Crittenden, J., Liu, X. and Du, H., Groundwater remediation from the past to the future: a bibliometric analysis. *Water Res.*, 2017, **119**, 114–125.
12. Oraee, M., Hosseini, M. R., Papadonikolaki, E., Palliyaguru, R. and Arashpour, M., Collaboration in BIM-based construction networks: a bibliometric-qualitative literature review. *Int. J. Project Manage.*, 2017, **35**(7), 1288–1301.
13. Sarin, S., Haon, C. and Belkhouja, M., A bibliometric analysis of the knowledge exchange patterns between major technology and innovation management journals (1999–2013). *J. Prod. Innov. Manage.*, 2018, **35**(1), 2–8.
14. Yu, D. J., Xu, Z. S. and Wang, X. Z., Bibliometric analysis of support vector machines research trend: a case study in China. *Int. J. Machine Learn. Cyber.*, 2019, in press, doi:10.1007/s13042-019-01028-y.
15. Glänzel, W., Schubert, A. and Czerwon, H. J., A bibliometric analysis of international scientific cooperation of the European Union (1985–1995). *Scientometrics*, 1999, **45**(2), 185–202.
16. Duan, L., Analysis of the relationship between international cooperation and scientific publications in energy R&D in China. *Appl. Energ.*, 2011, **88**(12), 4229–4238.
17. Li, W. and Zhao, Y., Bibliometric analysis of global environmental assessment research in a 20-year period. *Environ. Impact Assess. Rev.*, 2015, **50**, 158–166.
18. Merigó, J. M., Cancino, C. A., Coronado, F. and Urbano, D., Academic research in innovation: a country analysis. *Scientometrics*, 2016, **108**(2), 559–593.
19. De Paulo, A. F. and Porto, G. S., Solar energy technologies and open innovation: a study based on bibliometric and social network analysis. *Energ. Policy*, 2017, **108**, 228–238.
20. He, X. R., Wu, Y. Y., Yu, D. J. and Merigó, J. M., Exploring the ordered weighted averaging operator knowledge domain: a bibliometric analysis. *Int. J. Intell. Syst.*, 2017, **32**(11), 1151–1166.
21. Yu, D. J., Xu, Z. S, Pedrycz, W. and Wang, W., Information Sciences 1968–2016: a retrospective analysis with text mining and bibliometric. *Inform. Sci.*, 2017, **418**, 619–634.
22. Yu, D. J. and Meng, S., An overview of biomass energy research with bibliometric indicators. *Energ. Environ.*, 2018, **29**(4), 576–590.
23. Weingart, P., Impact of bibliometrics upon the science system: inadvertent consequences? *Scientometrics*, 2005, **62**(1), 117–131.
24. Fu, H. Z., Chuang, K. Y., Wang, M. H. and Ho, Y. S., Characteristics of research in China assessed with Essential Science Indicators. *Scientometrics*, 2011, **88**(3), 841–862.
25. Cova, T. F., Pais, A. A. and Formosinho, S. J., Iberian universities: a characterisation from ESI rankings. *Scientometrics*, 2013, **94**(3), 1239–1251.
26. Merigó, J. M., Pedrycz, W., Weber, R. and de la Sotta, C., Fifty years of *Information Sciences*: a bibliometric overview. *Inform. Sci.*, 2018, **432**, 245–268.
27. Yu, D. J., Xu, Z. S. and Šaparauskas, J., The evolution of *Technological and Economic Development of Economy*: a bibliometric analysis. *Technol. Econ. Dev. Econ.*, 2019, **25**(3), 369–385.
28. Van Eck, N. J. and Waltman, L., Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 2010, **84**(2), 523–538.
29. Van Eck, N. J. and Waltman, L., Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics*, 2017, **111**(2), 1053–1070.
30. Wong, D., VOSviewer. *Tech. Serv. Q.*, 2018, **35**(2), 219–220.
31. Cheng, Y., Johansen, J. and Hu, H., Exploring the interaction between R&D and production in their globalisation. *Int. J. Oper. Prod. Manage.*, 2015, **35**(5), 782–816.

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