Comparison of environmental laws publications in Science Citation Index Expanded and Social Science Index: a bibliometric analysis

Rongzhen Ma[1,2] · Yuh-Shan Ho[1,2]

Abstract This study presents an analysis of environmental law research in the natural science and social science fields from a bibliometric perspective. Document type, publication language, annual output, and distributions of countries were quantitatively characterized and compared in the Science Citation Index Expanded (SCI-EXPANDED) and the Social Science Index (SSCI). The citation history of highly cited articles and word analysis were used to examine research tendencies and "hotspots" in environmental law research. The results show that from 1992 to 2014 SCI-EXPANDED has published more research in environmental laws than SSCI except in 2011. The USA is the most productive country in both databases. Developing countries such as China, India, and Brazil are among the top 10 productive countries in SCI-EXPANDED, while in that of SSCI, China is the only developing country. The USA had the most frequent collaborations with other countries both in SCI-EXPANDED and SSCI; collaborations were more frequent in SSCI than in the SCI-EXPANDED. Words analysis reveals that "sustainability", "compliance", and "environmental management" are key issues in SSCI, while articles in SCI-EXPANDED pay more attention to "risk assessment", "recycling", "wastewater treatment", and "temperature". "China" is a key issue in research in both natural science and social science field, which indicates the rapid development of environmental law research in China as well as the growing concerns of China's environmental law issues.

Keywords Environmental law · Scientometrics · SCI-EXPANDED · SSCI

✉ Yuh-Shan Ho
ysho@asia.edu.tw

1   College of Environmental Sciences and Engineering, Peking University, Beijing 100871, China

2   Trend Research Centre, Asia University, No. 500, Lioufeng Road, Wufeng 41354, Taichung County, Taiwan

Introduction

With the growing number of environmental crises all over the globe, such as global warming, pollution, natural resource depletion, deforestation, and loss of biodiversity, the development of effective environmental laws and regulations has taken on added urgency, focusing greater importance on environmental law research. In the last twenty years, a significant part of environmental legal research has focused on economics and management (Revesz 1992; Henriques and Sadorsky 1996; Buysse and Verbeke 2003), biology (Vescovi et al. 1996), and industry (Oyama 2003; Lang and Wai 2001). For decades, environmental laws and regulations related research has become a multidisciplinary field which covers a wide spectrum of studies in environmental sciences (Stanislaus et al. 2010), management sciences (Khanna and Damon 1999), politics (Agrawal and Knoeber 2001), and law (Biber 2012). Effective environmental laws and regulations must rely on sound environmental science, and the inevitable uncertainty in environmental science means that policy will necessarily intertwine with science (Biber 2012). However, the bibliometric characteristics of environmental law research have not been identified. Moreover, research concerning environmental law can be categorized by different subtopics in natural science and social science. We might see natural science and law in a new way by comparing research in multiple disciplines. A comparison of publications in the SSCI and SCI-EXPANDED databases provides a means of assessing the current status of available research.

Bibliometrics has been widely used to characterize the literature of a research field (Vergidis et al. 2005; Falagas et al. 2006). The number of publications, distributions of countries, and Web of Science subject category patterns are usually employed to assess publication performance (Ho 2012, 2013). In addition, Ho and his co-workers proposed the "Word Cluster Analysis" method to characterize research trends and hotspots for a particular topic (Mao et al. 2010). The publication characteristics of many research topics related to the environment have been evaluated through bibliometric analysis, for example, drinking water (Fu et al. 2013), aerosols (Xie et al. 2008), water resources (Wang et al. 2011), and estuary pollution (Sun et al. 2012). However, traditional bibliometric analyses only characterized the publication performance of certain topics in either SCI-EXPAN-DED (Ho and Kahn 2014) or SSCI (Ho 2014). A comparison of the same topic from these two databases is rarely conducted. Moreover, many studies only use limited original data, and a select number of journals or categories to represent global research trends related to a topic (Mela and Cimmino 1998; Klein and Hage 2006). More information, including source, title, author, keyword, *KeyWords Plus*, and abstracts should be introduced in the study of research trends (Xie et al. 2008; Li et al. 2011). To present a comprehensive picture of environmental law research in the scientific world, multi-evaluations of publication performance are required. This study presents a bibliometric analysis of environmental law research in the SSCI and SCI-EXPANDED databases respectively, between 1992 and 2014. Document types, publication language, annual outputs of publications, distributions of countries, and citation life cycles of highly cited articles were quantitatively analyzed and compared in SSCI and SCI-EXPANDED. Word analysis was also used to characterize research tendencies and hot issues in the environmental law field. The comparison of publication performance of environmental law research in SSCI and SCI-EXPANDED can help identify the characteristics of research content and trends for the same topic in different research fields.

Methodology

The data for this article has been sourced from the online versions of the SCI-EXPAN-DED, the SSCI, and the Thomson Reuters' Web of Science databases. According to *Journal Citation Reports* (*JCR*), in 2014 SCI-EXPANDED included 8659 journals with citation references across 175 Web of Science subject categories, while the SSCI included 3154 journals with citation references across 56 categories. "Environmental law", "environmental laws", "environmental regulation", and "environmental regulations" were searched in terms of topic (including four parts: title, abstract, author keywords, and *KeyWords Plus*) within the publication years 1992 to 2014. *KeyWords Plus* supplied additional search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes in the Institute for Scientific Information (now Thomson Reuters, New York) database, substantially augmenting title-word and author-keyword indexing (Garfield 1990). In total, 3860 documents met the selection criteria. Downloaded information for each article included names of authors, affiliation, document title, year of publication, Web of Science categories, and citations in each year. The records were downloaded into a spreadsheet, and additional coding was manually performed for the number of authors, country of origin of the collaborators, and impact factors of the publishing journals using Microsoft Excel 2013 (Li and Ho 2008). Impact factors (IF_{2014}) were taken from the *JCR* published in 2014. In the SCI-EXPANDED and SSCI databases, the corresponding author is designated as the "reprint" author; this study instead used the term "corresponding author" (Ho 2012). In a single author article where authorship was unspecified, the single author was both first author and corresponding author (Ho 2012). Similarly, for a single institution article, the institution was classified as both the first author's institution and the corresponding author's institution (Ho 2013). Articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK) (Chiu and Ho 2005). Articles from Hong Kong published before 1997 were included in the China category (Chuang et al. 2011). Articles from USSR were checked and reclassified as being from Russia (Ho 2012). Articles from Zaire were reclassified as being from the Democratic Republic of the Congo (Dem Rep Congo).

Results and discussion

Document type

In total, 4689 documents including 2904 from SCI-EXPANDED and 2341 from SSCI, were found in 13 and 14 document types respectively. There were 474 articles published in journals in both SCI-EXPANDED and SSCI. A total of 85 % of documents in SCI-EXPANDED and 79 % of documents in SSCI were articles (Table S1 in the Supplemental Material). The number of total citations (TC_{2014}) since publication year to the end of 2014 from the Web of Science Core Collection (Chuang et al. 2011) was further considered for the citations per publication ($CPP = TC_{2014}/TP$), as distributed between the two databases (Chuang and Ho 2015). The total citations (*TC*) in the Web of Science Core Collection could be changed from over time. The advantage of using TC_{2014} is that it is an invariant parameter, which ensures repeatability, while the index of citations would have been updated from time to time (Fu et al. 2012). The average *CPP* values were 13 and 12 for articles published in SCI-EXPANDED and SSCI respectively. Only articles were used for further analysis (Ho et al. 2010).

Language of publication

The language distributions of all articles published in SCI-EXPANDED and SSCI are illustrated in Table S2 in the Supplementary Material. Of the total 3860 documents, 3741 (97 %) were published in English, followed by German (32 articles), Spanish (26), French (17), Portuguese (14), Japanese (7), Polish (4), Chinese (3), Czech (3), Finnish (2), Russian (2), Turkish (2). Compared with SCI-EXPANDED, SSCI has a higher percentage of English-written documents, 99 %. Such a high percentage of English documents was also reported for the topic of wetland research (Zhang et al. 2010). Non-English articles have less citations, with an average of 1.1 citations per article, while English articles have an average of 13 citations. The non-English article with the highest citations was "Sustainable development and Green Chemistry" (da Silva et al. 2005) published in Portuguese in *Quimíca Nova*, with a TC_{2014} of 13.

Publication output

The productivity of publications gives an overview of the development of different research topics. Numerous studies have analyzed the annual outputs of publications for different environmental research fields, for example, the top-cited wetland articles (Ma et al. 2013) and research on estuary pollution (Sun et al. 2012). The annual number of articles and citations per publication (*CPP*) in SCI-EXPANDED journals and SSCI journals are illustrated in Fig. 1 to identify research developments in the field of environmental law. The total number of articles shows a rapid growth trend, rising from 92 articles in 1992 to 280 articles in 2014. The productivity of SCI-EXPANDED was higher than SSCI for many years, with a similar increasing trend in the period of 1992 to 2008. The high number of articles from SSCI in 2012 is most likely attributable to the increased popularity of research in environmental economics (Costantini and Mazzanti 2012; Ryan 2012).

There was a large difference in the *CPP* in different years. In SSCI, the article with the highest citation focused on American federal environmental regulation (Revesz 1992), $TC_{2014} = 278$. Similarly, in 2005, 109 articles in SCI-EXPANDED had an average *CPP* of 23, higher than that for articles published in SSCI in the same year. This can be attributed to the article entitled "Nanoparticle networks reduce the flammability of polymer nanocomposites" (Kashiwagi et al. 2005) with TC_{2014} of 323.

Distributions of countries/territories

A total of 3715 articles with author affiliations were distributed in 97 countries/territories. The top 10 most productive countries in SCI-EXPANDED and SSCI are listed in Table 1. Three of the top 10 productive countries in SCI-EXPANDED were developing countries (China, India, and Brazil), while only one (China) made the top 10 in SSCI. The USA is the most dominant country, producing 895 articles (38 % of total articles) in SCI-EXPANDED and 909 articles (50 %) in SSCI. The USA has the most single country articles and internationally collaborative articles, followed by UK and Canada. These three countries were deemed to be the most advanced countries in environmental law research, of which the USA was doubtlessly the leading country, with its total publications over four times more than the next most productive country in both SCI-EXPANDED and SSCI.
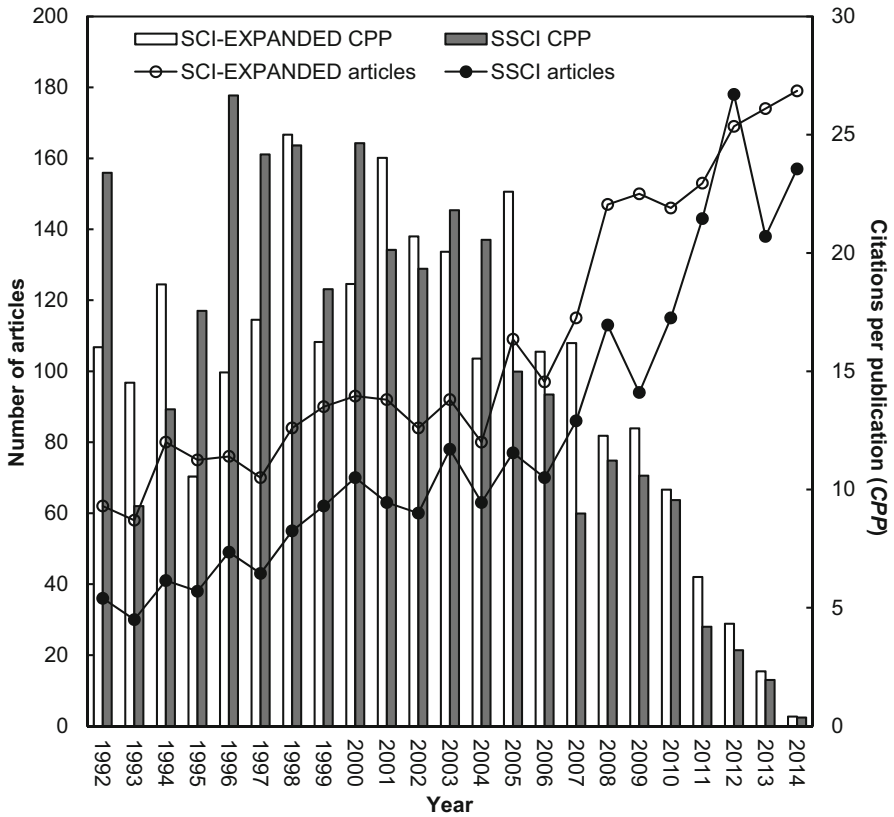
Fig. 1 Annual number of articles and citations per publication by year

Table 1 The top 10 most productive countries

SCI-EXPANDED				SSCI			
Country	TP (%)	IPR (%)	CPR (%)	Country	TP (%)	IPR (%)	CPR (%)
USA	893 (38)	1 (37)	1 (39)	USA	909 (50)	1 (50)	1 (45)
UK	177 (7.4)	2 (5.6)	2 (17)	UK	205 (11)	2 (9.3)	2 (20)
Canada	170 (7.1)	3 (5.4)	3 (16)	Canada	116 (6.4)	3 (4.6)	3 (15)
Germany	123 (5.2)	5 (3.8)	4 (12)	Germany	91 (5.1)	4 (3.8)	6 (11)
China	119 (5.0)	4 (4.2)	6 (9.2)	Australia	78 (4.3)	5 (3.4)	8 (8.4)
France	92 (3.9)	8 (2.6)	5 (10)	China	77 (4.3)	7 (2.3)	4 (14)
Spain	81 (3.4)	8 (2.6)	8 (7.7)	Netherlands	67 (3.7)	8 (1.9)	5 (12)
India	77 (3.2)	6 (2.9)	11 (5.1)	Spain	61 (3.4)	6 (2.5)	9 (7.1)
Japan	73 (3.1)	12 (2.2)	8 (7.7)	France	54 (3.0)	12 (1.4)	6 (11)
Brazil	71 (3.0)	7 (2.8)	14 (3.8)	Italy	36 (2.0)	9 (1.6)	14 (3.6)

TP (%): total number of articles and the percentage of total articles, IPR (%): rank and percentage of single country articles, CPR (%): rank and percentage of internationally collaborative articles

Figure 2 illustrates the annual number of articles from the five most productive countries during 1992–2014. The USA is the leader in the publications, but showed a fluctuating growth during the period, with a peak of 107 articles (77 from SSCI and 46 from SCI-EXPANDED) in 2012. It should be noted that the sum of publications from SSCI and SCI-EXPANDED respectively was not equal to the total publications, because some articles were published in journals contained in both databases. China published no more than five articles each year from 1992 to 2007. However, the number has increased dramatically since 2007, reaching 41 publications in 2014 (36 from SCI-EXPANDED and 18 from SSCI), higher than those from the UK, Canada, and Germany. This indicates that China has made great progress and developed rapidly in environmental law research in recent years. The increased number of publications is mainly attributed to publications from SCI-EXPANDED rather than from SSCI.

As shown in Figs. 3 and 4, the collaboration relationship among top 10 most productive countries were visualized using social network analysis (Lienert et al. 2013). The data was analyzed in UCNET, which was commonly deployed in other bibliometric studies (Wang et al. 2013). The thickness of the interconnecting line represents the collaboration frequency. In the SSCI, the USA had most frequent collaborations with other countries, such as China, Canada, and the UK. Similarly, the USA also had more collaborative relations
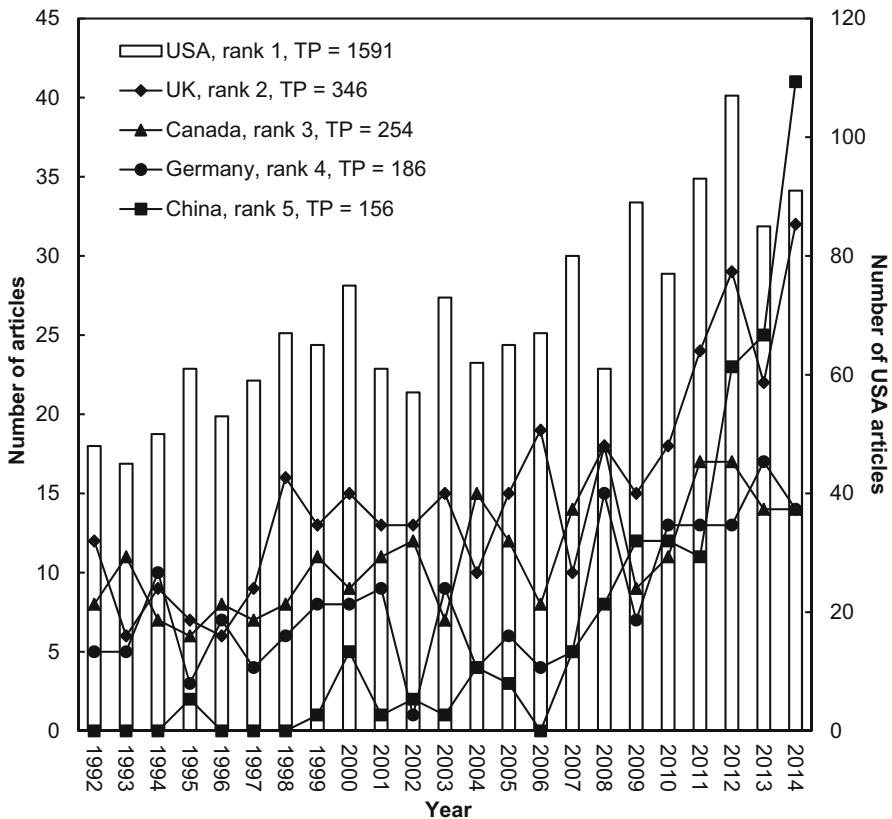

Fig. 2 Articles of the five most productive countries during 1992–2014
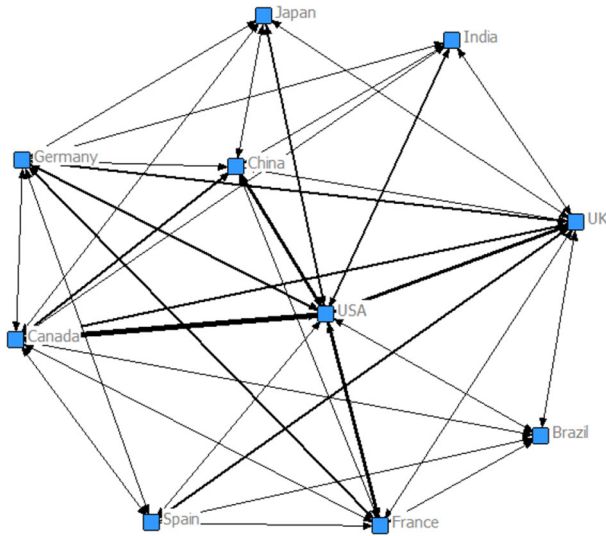
Fig. 3 Collaboration network of the top 10 most productive countries (SCI-EXPANDED)
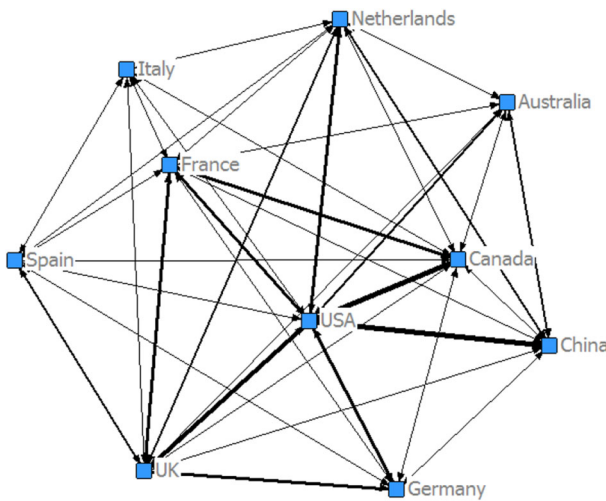

Fig. 4 Collaboration network of the top 10 most productive countries (SSCI)

with other productive countries in the SCI-EXPANDED, including Canada, the UK and China. However, from Figs. 3 and 4, it can be seen that the collaborations were more frequent in SSCI than in the SCI-EXPANDED, which means that social science research in the environmental law field might need more collaboration.

Citation history

The number of citations of an individual article can reveal its impact or visibility in the research community (Wohlin 2005). Figure 5 shows the relationship between the *CPP* and

the number of years since its publication for articles published in SCI-EXPANDED and SSCI. In SSCI, although the greatest increase in *CPP* occurs during the first two years since publication, it does not reach its peak until the 5th year. The "5th peak year phenomenon" was also found in contingent valuation research (Li and Ho 2008). Hansen and Henrikson (1997) found that the number of citations per year reached a maximum or plateau 3–7 years after publication, while a general maximum was 2–3 years. The phenomenon that the citation mode may drift from 2 to 3 years also exists in other disciplines, like typology (Vlachy 1985), medicine, and biochemistry (Cano and Lind 1991). However, the topic of environmental laws is special, as there is a second rise of *CPPs* from the 6th year after publication in SSCI.

Figure 6 shows the citation histories of the top eight cited articles related to environmental laws. The top four ranked articles were published in SCI-EXPANDED, while three (ranking from 5th to 8th) were published in SSCI. The article entitled "Do corporate global environmental standards create or destroy market value?" (Dowell et al. 2000) was published in *Management Science* which is in both SCI-EXPANDED and SSCI. The citations of articles which examined frontier scientific issues, such as biotechnology (Jang and Sheen 1994), increased rapidly since publication. In comparison, articles from SSCI rose slowly.
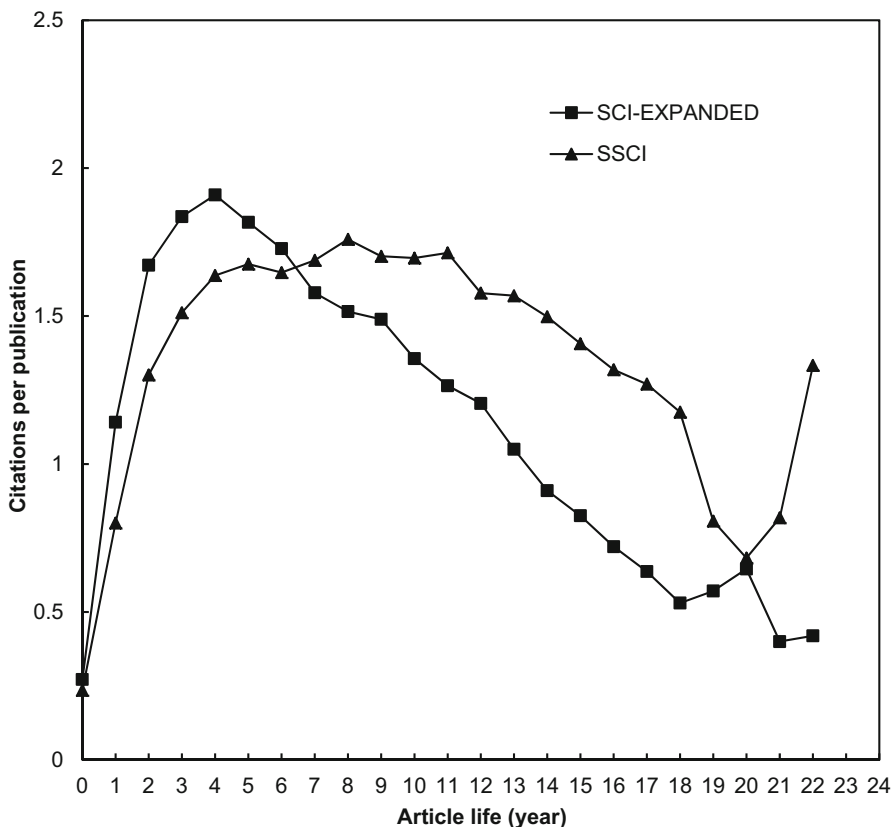

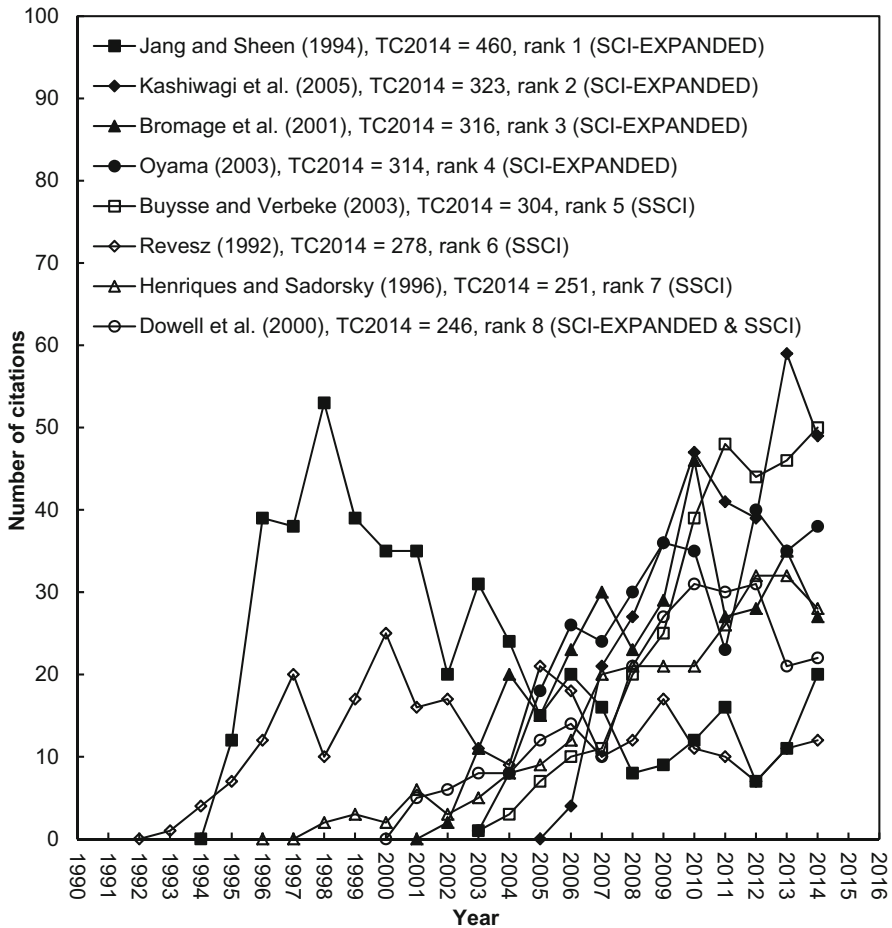**Fig. 5** Citations per publication by article life

Fig. 6 Citation history of the top eight cited articles

Research tendency and hotspots

The trends and hotspots of research topics are extremely important as they can provide clues for finding a new breakthrough point in a research field. In recent years, Ho and coworkers used the distribution of words in article titles and abstracts, author keywords, and *KeyWords Plus* to evaluate research trends (Xie et al. 2008; Zhang et al. 2010). Word Cluster Analysis using information from word distribution results has also been applied in research trend studies (Mao et al. 2010). To characterize the research tendency and hot issues in environmental law research, synthesized analysis of title words, author keywords, abstracts, and *KeyWords Plus* was conducted.

Among 3860 articles, 3648 (95 %) articles have information of their abstracts recorded in Web of Science, 2423 (63 %) articles have author keywords, and 2640 (68 %) articles have *KeyWord Plus*. Individual words separated from titles and abstracts would sometimes bias their meaning and not make sense, and *KeyWords Plus* were not necessarily associated with the content of articles (Fu et al. 2013). Consequently, author keywords were

preferentially adopted to characterize research tendency and hotspots. The top 20 author keywords used most frequently during 1991–2014 and one five-year (1992–1996) and three six-year periods in SCI-EXPANDED and SSCI are listed in Tables S3 and S4 in the Supplemental Material, respectively. It is surprising to find that other than the keywords "environmental regulation(s)", "environmental law(s)", and "environmental policy", the most frequently used author keyword in both SCI-EXPANDED and SSCI was "China".

China, as the second largest economic entity, has been suffering from severe environmental pollution caused by the rapid urbanization and industrialization over the last few decades. Therefore, environmental law and regulation research are urgently needed to provide support for addressing China's environmental problems. Other frequently used words on the list of top 20 in both SCI-EXPANDED and SSCI were "sustainability", "compliance", "environmental management", "uncertainty", and "pollution". Those topics are all related to development and environmental governance. However, there are also obvious differences in the top 20 most frequently used words from SCI-EXPANDED and SSCI. "Risk assessment", "recycling", "wastewater treatment", "temperature", and "heavy metals" were included in the SCI-EXPANDED top 20, while "climate change", "international environmental law", "enforcement", "porter hypothesis", "environmental performance", "governance", and "trade" were included in the SSCI top 20. This
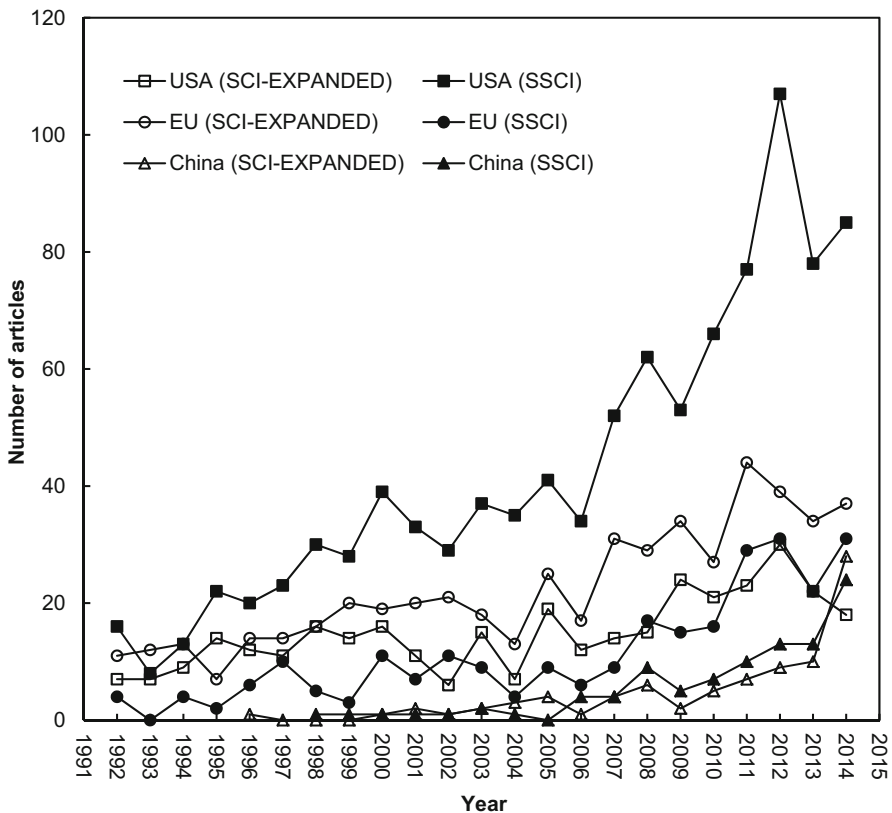

Fig. 7 Comparison of trends of articles with related topics from USA, EU, and China in SCI-EXPANDED and SSCI databases

demonstrates that there are different core concerns in natural science and social science for the topic of environmental law.

The Word Cluster Analysis method was also used to further examine the development of research topics (Mao et al. 2010). Author keywords, *KeyWords Plus*, and separated words from titles and abstracts were combined as the word base. Then a series of "word clusters", groups of synonymic single words and congeneric phrases, were selected by the researchers using their specialized knowledge, to represent the possible research hotspots of this field. Each word cluster was composed of several supporting words. The word cluster could then be searched as the combined words' base in the abstracts of related publications. Finally, by analyzing the number of publications containing these word clusters, several research hotspots could be revealed (Mao et al. 2010). In this study, USA (supporting words including USA, U.S., United States, and America), EU (E.U., European, and Europe), and China (China and Chinese) were selected as the main research topics. The growth trends in the number of articles related to the USA, the EU, and China are compared in Fig. 7. The topic "USA" has been leading in 20 years in SSCI articles, followed by "EU". For SCI articles, the "EU" topic was more popular, especially in recent years. There was a sharp increase in articles relating to China from 2013 to 2014 in both SCI-EXPANDED and SSCI, reinforcing the evidence from word analysis. It is surprising to find that almost all the articles relating to "China" in 2013 and 2014 were based on China's environmental practical experiences, including empirical evidence of eco-innovation from Chinese enterprises (Dong et al. 2014), China's environmental courts (Stern 2014), firm's strategies (Zhu et al. 2014), empirical analysis on BML index (Du et al. 2014), and China's industrial carbon emissions (Ren et al. 2014). It might be inferred that China has done a lot in the environmental field in recent years, both institutionally (Mu et al. 2014) and practically. The large amount of articles on China's environmental laws indicate that regulations and laws have become a significant tool to solve environmental crises.

Conclusions

This study investigated environmental law research in both natural science and social science. English documents had higher citations in both databases. The citation history of certain articles shows that environmental law research was given an increasing amount of attention over the period of 1992 to 2014. SCI-EXPANDED produced more articles than SSCI for a long period. Developing countries such as China, India, and Brazil are among the top 10 productive countries in SCI-EXPANDED, while in that of SSCI, China is the only developing country. The USA is the dominant country in both two databases. The USA had the most frequent collaborations with other countries both in SCI-EXPANDED and SSCI, collaborations were more frequent in SSCI than in the SCI-EXPANDED.

Synthesized analysis of title words, author keywords, abstract, and *KeyWords Plus* provided clues for hot topics. "China", "sustainability", "compliance", and "environmental management" are hot issues in social science, while SCI-EXPANDED articles paid more attention to "China", "risk assessment", "recycling", "wastewater treatment" and "temperature". Apparently, "China" has become a popular area for research in both natural science and social science when it comes to environmental laws, indicating the rapid development of environmental law research in China and the growing concerns of China's environmental law issues. Regarding environmental issues in China, scientific

research often focuses on risk assessment, recycling, wastewater treatment, temperature, heavy metals etc., while social science studies pay more attention to the topics of climate change, international environmental law, enforcement, and environmental economy.

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