

## Global Environmental Impact Assessment Research Trends (1973-2009)

Zhuang Yanhua, Hong Song<sup>a</sup>, Lin Hongyan, Niu Beibei

*School of Resource and Environmental Science, Wuhan University, Wuhan 430079, China*

*<sup>a</sup>E-mail: [songhongku@126.com](mailto:songhongku@126.com)*

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### Abstract

According to the samples of 1781 literatures about environmental impact assessment (EIA) of SCI and SSCI databases from 1973 to 2009, this paper analyzes the literatures in their trend of growth, subject categories and journals, International collaborations, geographic distribution of publications and scientific research issues by using bibliometrics analysis. The result shows that EIA research steadily increases over the past 40 years and the annual number of papers published in 2009 is 50 times than that in 1973. EIA was involved into 130 kinds of subjects and appeared in 587 journals. The main study area with strong scientific research capabilities distributed in USA and European Union, while the USA was the largest contributor in EIA research and had a central position in collaboration networks. A keyword analysis found that the priority in assessment would gradually change from project environmental impact assessment to Strategic Environmental Assessment (SEA) and Plan Environmental Impact Assessment (PEIA); EIA research would focus on using and improving new techniques and methods, such as “life cycle assessment (LCA)”, “geographic information system (GIS)” and “modeling” etc.; “biodiversity” and “climate change” would attract more attention and will be the emphasis of EIA; the improvement of developing countries’ EIA system became popular research. This study reveals patterns in scientific outputs and academic collaborations and serves as an alternative and innovative way of identifying global research trends in EIA.

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### 1. Introduction

Environmental impact assessment is the assessment of the possible impact (positive or negative) that proposed project may have on the environment, considering natural, social and economic aspects[1]. Classified by the evaluated objects, EIA includes project environmental impact assessment, plan environmental impact assessment and strategic environmental assessment. With the regionalization and globalization of environmental problems, transboundary environmental impact assessment was also drawing increasing attention[2].

EIA regime was first determined in legal form in the USA in 1969, then it was introduced in succession to many other countries. This economic growth largely based on industrial output is fast degrading the ecosystems and jeopardizing their long term sustainability in developing countries. EIA has long been recognized as a tool which can help in protecting the ecosystems and aid sustainable development[3].

Bibliometric analyses have been conducted to reveal the global trends of various research fields[4,5]. Bibliometric analysis of global EIA research trends has not yet been found, so a comprehensive statistical review of the global EIA research is needed. In this study, bibliometric methods were used to quantitatively and qualitatively investigate the global research trends of EIA studies during the period of 1900-2009.

The study can facilitate the discussion of future development of EIA research and help guide researchers in this

dynamically developing field.

## 2. Materials and Methods

The data were based on the online version of SCI and SSCI, Web of Science, which are multidisciplinary database of the Institute for Scientific Information (ISI), Philadelphia, USA. “Environ\* impact assess\*” or “strategic\* environ\* assess\*” ( including “environmental impact assessment”, “plan environmental impact assessment”, “strategic environmental impact assessment”, “strategic environmental assessment” , et al.) were used as keywords to search all papers that contained these words in title, abstract, or keywords. All papers, published in journals “environmental impact assessment review” and “computer support for environmental impact assessment”, were also gathered.

Publications originating from England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK). Publications from Hong Kong were not included in China [6,7]. Besides, the reported impact factor (IF) of each journal was obtained from the 2009 Journal Citation Reports (JCR). Collaboration type was determined by author description, where “independent” was assigned if no collaboration was presented. “International collaboration” was assigned if it was cosigned with researchers from more than one country[7].

Although documents published were searched from 1900 to 2009, the earliest EIA-related publications were published in 1973. Using the above mentioned searching strategy, a total of 1781 publications were identified as being EIA-related in the SCI and SSCI database.

All the papers referring to EIA were assessed in the following aspects: publication outputs, subject categories and major journals, geographic and institutional distribution of publications, and keywords analysis.

## 3. Results and Discussion

### 3.1. Document type and language of publication

The distribution of the document type identified by ISI was analyzed. From this study, 13 document types were found in the total 1781 publications during 1973-2009. Article (1285) was the most-frequently used document type comprising 72.15% of the total production, followed by proceedings paper (277; 15.55%), review (69; 3.87%), book review (68; 3.82%), editorial material (48; 2.70%), and meeting abstract (14; 0.79%). The others showing less significance were letter (6; 0.34%), discussion (5; 0.28%), note (4; 0.22%), correction (2; 0.11%), news item (1; 0.056%), correction, addition (1; 0.056%), and reprint (1; 0.056%).

The distribution related to the language of publication was also analyzed. Ninety-seven percent of all these documents were published in English (1728). Several other languages also appeared, containing German (27; 1.52%), French (8; 0.45%), Spanish (7; 0.39%), Japanese (5; 0.28%), Slovak (2; 0.11%), Croatian (1; 0.056%), Slovene (1; 0.056%), Portuguese (1; 0.056%), Polish (1; 0.056%), et al. English remains the dominant language in EIA research. A higher percentage of English would be used because more journals listed in ISI were published in English [9].

### 3.2. Characteristics of Publication Outputs

The total amounts of SCI and SSCI publications related to EIA research during 1973-2009 were counted and displayed in Fig. 1. Obvious attention to EIA research did not emerge until the 1990s, although a few publications related to EIA were published previously. Along with the development of SCI and SSCI, EIA research continually grew in this long period ,started to go up significantly in the year of 1990 and rocketed in the past two decades.The annual number of publications on EIA exploded from 5 in 1973 to 250 in 2009.

Documents on EIA published in 1986 and the period of 1995 to 2007 received higher total citations, which shows that EIA research has gradually caused widespread concern during the past 15 years.

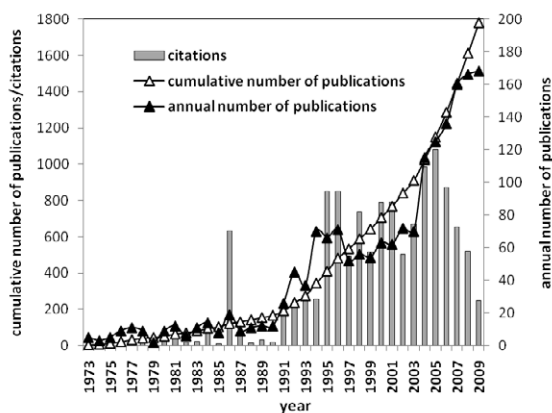


Figure 1. Characteristics by year of publications

### 3.3. Subject Categories and Journals

Publications on EIA covered 130 ISI identified subject categories in SCI and SSCI. The five most common subject categories are “environmental sciences” (584;32.79%), “environmental studies” (496; 27.85%), “water resources” (158; 8.87%) , “engineering, environmental” (154; 8.65%) and “ecology” (135; 7.58%). Each of these five subjects included more than 100 papers.

Publications on EIA appeared in 587 journals. Table I shows the top 10 productive journals with quantitative and citation attributes. Above 33.3% of the total EIA-related publications reside in these 10 core journals. The “environmental impact assessment review”, an journal devoted to EIA research, ranked first with 298 (16.73%); “journal of environmental management”, “environmental management”, “environmental monitoring and assessment”, “water science and technology” ranked at 2nd, 3rd, 4th, and 5th respectively. EIA publications that were published in these journals had received, on average, 6.85 citations, which was much higher than these journals’ average impact factors(1.70). This finding suggests that publishing papers on EIA have contributed positively to journals’ impact factors, and confirms the steady exchange of EIA research. Several journals released papers with highly average citations, including the following: “biological reviews” (1 paper on EIA with 206 citations), science(1 paper with 137 citations), “ecology”(4 papers with 133 average citations), “american sociological review”(1 paper with 130 citations).

TABLE I. COMPARISON OF THE TOP 10 MOST ACTIVE JOURNALS IN EIA RESEARCH

Journals	TP(%)	TC(%)	TC/TP	IF
environmental impact assessment review	298(16.73)	1799(14.33)	6.04	1.659
journal of environmental management	64(3.59)	529(4.21)	8.27	2.367
environmental management	58(3.26)	502(4)	8.66	1.408
environmental monitoring and assessment	34(1.91)	193(1.54)	5.68	1.356
water science and technology	34(1.91)	116(0.92)	3.41	1.094
computer support for environmental impact assessment	29(1.63)	10(0.08)	0.34	-
international journal of environment and pollution	24(1.35)	122(0.97)	5.08	0.624
desalination	18(1.01)	116(0.92)	6.44	2.034
marine pollution bulletin	18(1.01)	268(2.14)	14.89	2.630
landscape and urban planning	16(0.9)	155(1.23)	9.69	2.170

Total	593(33.3)	3810(30.34)		
Average			6.85	1.70

TP, total number of publications; TC, total citations; IF, Impact Factor

### 3.4. International Collaborations and Geographic Distribution of Publications

Those 94 countries/territories participated in EIA research. The top 10 countries/territories were ranked based on number of total papers, along with the citations, percentage of independent publication and international collaboration publication (Table II). Out of these 10 countries, 2 were from North America, 5 were from Europe, 2 were from Asian, and 1 was from Oceania. The USA produced most publications(290), followed by UK(275), Canada(141), and Australia(112). The USA was the most powerful country in comprehensive research strengths with most publications and citations. In top 10 countries, the average proportion of independent and internationally-collaborative respectively maked up 74.86% and 25.14%, which indicates that independent research dominates in these countries.

TABLE II. TOP 10 MOST PRODUCTIVE COUNTRIES FROM 1973 TO 2009

Country	TP(%)	TCR(%)	TC/TP	IP(%)	CP(%)
USA	290(16.28)	1(19.34)	9.87	76.90	23.10
UK	275(15.44)	2(14.07)	7.57	85.09	14.91
Canada	141(7.92)	3(8.08)	8.48	83.69	16.31
Australia	112(6.29)	4(7.88)	10.41	86.61	13.39
Germany	97(5.45)	7(3.59)	5.47	75.26	24.74
Netherlands	78(4.38)	5(4.57)	8.68	66.67	33.33
Italy	77(4.32)	6(3.78)	7.26	68.83	31.17
China	71(3.99)	14(2.3)	4.80	60.56	39.44
Sweden	53(2.98)	9(2.59)	7.23	73.58	26.42
Spain	49(2.75)	13(2.35)	7.10	71.43	28.57
Total	1224(74.13)				
Average			18.01	74.86	25.14

TP, total number of publications; TCR(%),rank and percentage of total citations; IP(%),percentage of independent publications; CP, percentage of international collaboration publications

Although both independent and internationally-collaborative papers increased in the last four decades, the annual proportion of independent papers decreased from 100% in 1973 to 78.79% in 2009, and the annual proportion of internationally-collaborative papers increased from 0% in1973 to 21.21% in 2009. The change in percentage of independent and internationally-collaborative suggests that the academic communities of EIA research gradually became more internationally connected(Fig. 2).

The relative importance of individual countries/territories in the collaboration network were measured, using UCINET network analytical software. UCINET identified a core group consisting of 48 countries/territories which hold relatively important positions in the international collaboration network on EIA researches (Fig. 3). The size of the corresponding nodes indicated number of internationally-collaborative publications, the thickness of the links indicated number of cooperation between the two countries. According to the size of the network nodes, it can be seen that USA, UK, China, Canada and Italy carry out more international cooperation in EIA research field, with numerous collaboration publications; Based on the the thickness of the links, The USA locates the core position in the collaboration network, closely cooperating with Canada, China, Italy and UK. The primary cooperation countries/territories of China are USA, UK and Hong Kong.

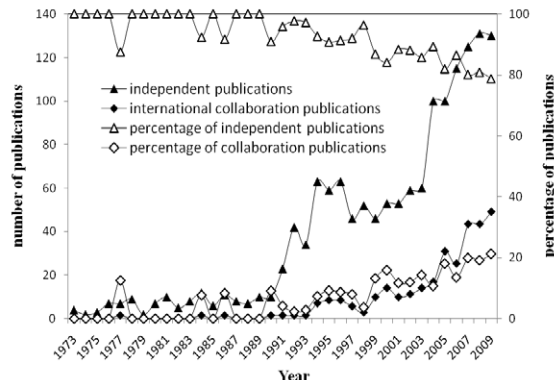


Figure 2. Characteristics by year of cooperation publications

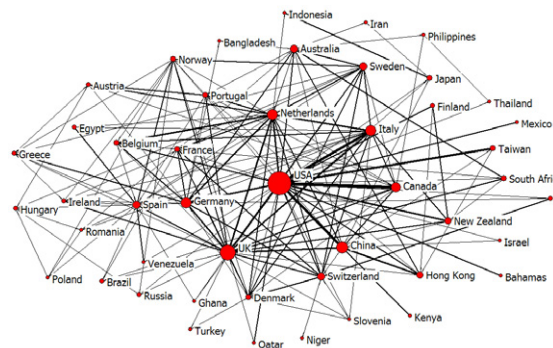


Figure 3. The cooperation of the major countries/territories

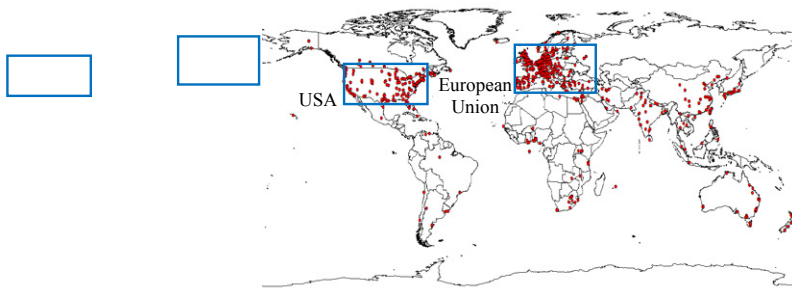


Figure 4. The world-wide geographic distributions of institutions

We geocoded the affiliations of author using CiteSpace[8] and plotted the world-wide geographic distribution of institutions (Fig. 4). The major spatial clusters of institutions locate in USA and European Union, followed by East Asia, several minor clusters distribute in other parts of the world. Africa, South America and Oceania did relatively less research.

### 3.5. Keywords Analysis

A keywords analysis was used to reveal the trend in EIA research and identify topics that draw most research efforts[9]. The keywords analysis in our study adopted author keywords as statistics objects. All author keywords related to EIA were statistically analyzed, and the 30 most frequent keywords within each 5-year intervals during 1990-2009 were presented in Table III.

The ranking of “strategic environmental assessment” and “planning” increased substantially to 2<sup>nd</sup> and 21<sup>th</sup>, which indicates that SEA and PEIA become important aspects of EIA gradually. In addition, the research scope of EIA is more extensive, from environmental contamination to ecological damage and social impact, “health impact assessment”, “risk

assessment”, “social impact assessment” progressively become the content of EIA. Many countries and territories have taken consideration of health, safety and social aspects in SEA[10].

EIA research would focus on applying and improving new techniques and methods. “Life cycle assessment” ranked at 3<sup>th</sup> in 1990-2009 with conspicuous growth trend. During the last century, LCA was mainly used in industrial fields, but nowadays, most researchers have used it widely to assess the impacts of products, processes and activities on the environment[11-17]. Additionally, some methods and principles, such as “geographic information system”, “public participation”, “modeling”, “monitoring”, “decision support system”, “analytic hierarchy process (AHP)”, “precautionary principle” and “uncertainty” are increasingly important in EIA. Evaluated objects of EIA were complexity and flexibility, modeling, monitoring, and other analysis method or system were widely used to improve the accuracy and reliability of the conclusion in EIA. In recent years the need to enhance public participation in EIA, and the efficacy of alternative mechanisms in achieving this goal, have been central themes in the EIA literature[18].

The “pollution”, “water quality”, “air pollution” and “waste management” have been the focus of EIA. In recent years, “biodiversity” and “climate change” have attracted worldwide attention, which were taken into the process of EIA. “Biodiversity” and “climate change” increased respectively from last to 21<sup>th</sup> and 25<sup>th</sup> during 1990-2009, and the increasing frequency of occurrence made them continue being the emphasis of EIA.

Currently, there is a gap between developing countries’ EIA and developed countries’ EIA. “Developing countries” ranked 678<sup>th</sup> in 1995-1999, and its rank soared to 25<sup>th</sup> by 2009. As one of the developing countries, the rank of “China” increased from 291<sup>th</sup> to 13<sup>th</sup> in the last two decades. The sight shows developing countries’ EIA are getting more attention.

TABLE III. FREQUENCY OF ANTHOR KEYWORDS USED IN PUBLICATIONS-TOP 30

	TP	90-94 R(%)	95-99 R(%)	00-04 R(%)	05-09 R(%)
environmental impact assessment	546	1(21.58)	1(38.13)	1(32.72)	1(35.23)
strategic environmental assessment †	122	33(0.53)	3(3.01)	2(6.28)	2(11.66)
life cycle assessment †	71	291(0)	8(2.01)	3(5.24)	3(5.96)
sustainable development	64	4(1.58)	4(2.34)	5(3.14)	4(5.56)
health impact assessment	38	291(0)	68(0.33)	4(4.19)	7(2.78)
geographic information system	38	33(0.53)	4(2.34)	8(2.09)	6(2.91)
risk assessment	33	9(1.05)	4(2.34)	8(2.09)	10(2.12)
public participation	33	33(0.53)	678(0)	10(1.57)	5(3.44)
modeling	32	9(1.05)	8(2.01)	21(0.79)	7(2.78)
monitoring	29	9(1.05)	4(2.34)	13(1.31)	11(1.99)
decision making	27	9(1.05)	17(1)	7(2.36)	13(1.72)
social impact assessment	21	33(0.53)	678(0)	42(0.52)	9(2.38)
environmental protection	21	9(1.05)	8(2.01)	10(1.57)	24(0.93)
environmental management	18	33(0.53)	14(1.34)	42(0.52)	15(1.46)
pollution	18	4(1.58)	68(0.33)	10(1.57)	21(1.06)
water quality	18	2(2.11)	12(1.67)	16(1.05)	28(0.66)
China †	17	291(0)	68(0.33)	21(0.79)	13(1.72)
decision support system	17	33(0.53)	17(1)	16(1.05)	19(1.19)
air pollution	16	9(1.05)	17(1)	13(1.31)	25(0.79)
Canada	15	33(0.53)	678(0)	21(0.79)	15(1.46)
waste management	15	291(0)	14(1.34)	128(0.26)	18(1.32)
analytic hierarchy process	15	291(0)	678(0)	16(1.05)	15(1.46)
Planning	15	291(0)	17(1)	16(1.05)	21(1.06)
effectiveness	11	291(0)	26(0.67)	1018(0)	19(1.19)
Biodiversity †	9	291(0)	678(0)	128(0.26)	21(1.06)
developing countries	9	9(1.05)	678(0)	128(0.26)	25(0.79)
precautionary principle	9	291(0)	26(0.67)	21(0.79)	41(0.53)
agriculture	8	291(0)	17(1)	42(0.52)	70(0.4)
climate change †	8	291(0)	68(0.33)	128(0.26)	25(0.79)
uncertainty	8	291(0)	26(0.67)	128(0.26)	28(0.66)

TP, total number of publications; R(%), rank and percentage of total citations; †, growth trend

#### 4. Conclusions

According to the bibliometric analysis, significant EIA-related research topics in SCI and SSCI database were obtained.

With the development of SCI and SSCI, EIA research continually grew during 1973-2009, and started to go up significantly in 1990. Our study suggests that “environmental sciences”, “environmental studies”, “water resources”, “engineering, environmental”, and “ecology” were the five most central subject categories in EIA research. The 10 most productive journals in EIA research, in terms of total publications, account for 33.30% of the total peer-reviewed publications on EIA, and the most active journals included “environmental impact assessment review”. The USA produced most papers, while the top five productive countries (USA, UK, Canada, Australia and Germany) produced 51.38% of the total publications. A network analysis also suggests the USA’s dominance among international collaboration network on EIA, and identifies a core group of 48 countries/territories. The increased collaboration index indicates the steady growth in academic production and exchange of EIA research. The keywords analysis confirms that most existed EIA researches were focus on research methods, such as LCA, GIS and modeling; following the project environmental impact assessment, SEA and PEIA have developed into important part of EIA; “health impact assessment”, “risk assessment”, and “social impact assessment” cause adequate attention in EIA research; Besides, global and long-term impact were paid increasing attention to, such as “biodiversity” and “climate change”. The improvement of developing countries’ EIA system became a hot topic to research.

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