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Research Trends in Non Point Source during 1975-2010

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Abstract

According to the samples of 2924 articles about non point source of SCI and SSCI databases from 1975 to 2010, this study analysed the articles in the growth trend of article outputs, subject categories and journals, international collaborations, geographic distribution and scientific research issues by using bibliometric analysis. The results showed that non point source research steadily increased over the past 35 years and the annual number of articles published in 2010 was 79 times of that in 1975. Non point source was involved into 67 kinds of subjects and appeared in 451 journals. The main study area was concentrated in North America and Europe, following by East Asia. There were 79 countries/territories participated in non point source research, and USA was the largest contributor in non point source research and had a central position in collaboration networks. A keyword analysis indicated that water quality, non point pollutions, and watershed were the hottest issues of non point source research; "GIS, "watershed management", "modeling", "simulation", "monitoring", and "remote sensing" were the most popular research methods; and "agriculture", "land use", "runoff", and "pollution" were the leading causes of non point pollution.

Keywords— non point source; bibliometric analysis; keywords analysis; research trends

1. Introduction

Non point source pollution has become increasingly prominent, making it an important factor that caused water environmental pollution [1,2]. As a brisk filed of the international water environment research, agricultural and urban non point source pollution attracted more and more attention around the world [3-6].

Bibliometric analysis is conducted to reveal the global trends of various research fields [7]. Bibliometric analysis of non point source has not yet been found, so a comprehensive statistical review of global non point source research trends is imperative. In this study, bibliometric methods were used to quantitatively and qualitatively investigate the global research trends of non point source studies during 1900-2010. A conventional bibliometric analysis of articles output, language, subject categories, journals, and country was used to describe recent advances in this field. Moreover, the new methods as spatial analysis and network analysis were used to simulate diagram of geographic distribution and international collaborations[8]. Furthermore, the author keywords were used to reveal the hot issues. The study can help guide researchers in this dynamically developing field.

2. Materials and Methods

The data were based on the online version of SCI and SSCI databases, Web of Science, which are multidisciplinary database of the Institute for Scientific Information (ISI). "Non point source*" or "nonpoint source*" (including "non point source", "non point sources", "non-point source", "non-point sources", "nonpoint source", "nonpoint sources", and "nonpoint-source", etc) were used as keywords to search all publications that contained these words in publications' titles, abstracts, or keyword lists from 1900-2010.

Publications originating from England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK). Publications from Hong Kong and Taiwan were not included in China [9,10]. Besides, the reported impact factor (IF) of each journal was obtained from the 2010 Journal Citation Reports (JCR). Collaboration

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type was determined by author attribution, where "single-country articles" was assigned if no collaboration was presented. "Internationally-collaborative articles" was assigned if it was cosigned with researchers from more than one country [10]. Different keywords with identical meaning and misspelled keywords were grouped into a single keyword.

Using the above mentioned searching strategy, the publications referring to non point source were identified. All the papers 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

3.1Document type and language of publication

The distribution of the document type identified by ISI was analyzed. From this study, 15 document types were found in the total 3128 publications. Article (2924) was the most-frequently used document type comprising 93.48% of the total production. The earliest non point source related article was published in 1975[11]. This study only focused on 2924 articles during 1975-2010 in further analysis.

The distribution related to the language of articles was also analyzed. Ninety-nine percent of all these documents were published in English (2904). Several other languages also appeared, containing French (7; 0.24%), Portuguese (6; 0.21%), German (4; 0.14%), Chinese (1; 0.03%), Danish (1; 0.03%), Polish (1; 0.03%), etc. English remained the dominant language in non point source research. A higher percentage of English would be used because more journals listed in ISI were published in English [12].

3.2Characteristics of Publication Outputs

The total amounts of SCI and SSCI articles related to non point source research during 1975-2010 were counted and displayed in Figure1. Along with the development of SCI and SSCI, non point source 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 articles on non point source exploded from 3 in 1975 to 238 in 2010. Figure1 also showed that the number of articles increased exponentially ($y=60.08e^{0.072x}$, $R^2=0.900$) during 1991-2010. It could predict that the number of articles on non point source will still grow rapidly in the future.

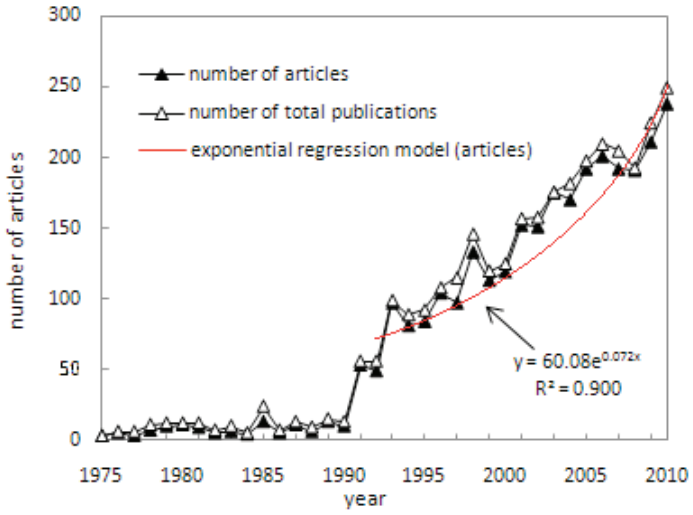

Figure1. Characteristics by year of publications during 1975-2010

3.3 Subject Categories and Journals

Articles on non point source covered 67 ISI identified subject categories in SCI and SSCI. The five most popular subject categories are "environmental sciences and ecology" (1652; 56.50%), "water resources" (1152; 39.40%), "engineering" (1014; 34.68%) , "agriculture" (541; 18.50%) and "ecology" (507; 17.34%). Each of these five subjects included more than 500 articles. This showed the recent emphasis on the impact of non point source in "environmental sciences and ecology" and "water resources".

Articles on non point source appeared in 451 journals. Table1 showed the top 10 productive journals with quantitative and citation attributes. Above 37.86% of the total publications resided in these 10 core journals. The "*Journal of the American Water Resources Association*" ranked first with 249 (8.52%); "*Water Science and Technology*", "*Journal of Environmental Quality*", "*Journal of Soil and Water Conservation*", "*Water Resources Bulletin*" ranked at 2nd, 3rd, 4th, and 5th, respectively. Non point source related articles which were published in these journals had received 21.34 citations on average, which was much higher than these journals' average impact factors (1.897). This finding indicated that articles on non point source had contributed positively to journals' impact factors, and confirmed the steady growth in exchange of non point source research.

Table1. Comparison of the top 10 most active journals in non point source research

	TP(%)	TC	TC/TP	IF2010
Journal of the American Water Resources Association	249(8.52)	3816	15.33	1.373
Water Science and Technology	193(6.6)	1563	8.10	1.056
Journal of Environmental Quality	129(4.41)	5213	40.41	2.236
Journal of Soil and Water Conservation	118(4.04)	2063	17.48	1.407
Water Resources Bulletin	86(2.94)	1469	17.08	-
Transactions of the ASAE	82(2.8)	1954	23.83	-
Environmental Science and Technology	68(2.33)	2490	36.62	-
Environmental Management	63(2.15)	981	15.57	1.503
Science of the Total Environment	63(2.15)	948	15.05	3.190
Journal of Hydrology	56(1.92)	1342	23.96	2.514
Total	1107(37.86)	21839		
Average			21.34	1.897

TP(%), total number and percentage of articles; TC, total citations; TC/TP, average citations per article; IF2010, impact factor in 2010

3.4 International Collaborations and Geographic Distribution of Publications

A total of 2908 articles included the author attributions, which included author address, source country and research institute. There were 79 countries/territories participated in non point source research. Based on the author attributions, the world-wide geographic distribution of institutions was plotted using CiteSpace[13]. The major spatial clusters of research institutes located in North America and Europe, following by East Asia (Figure2). Several minor clusters distributed in other parts of the world. Africa and South America did relatively less research.

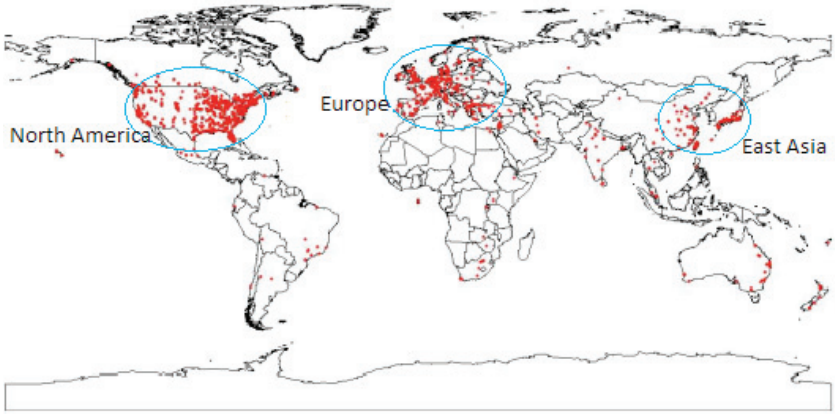

Figure2. The world-wide geographic distributions of research institutes

The top 10 countries/territories were ranked based on the number of total articles, along with the citations, percentage of single-country and internationally-collaboration publication (Table2). Out of these 10 countries, 2 were from North America, 3 were from Europe, 4 were from Asian, and 1 was from Oceania. The USA produced most publications(1947), followed by Canada(155), China(152), Germany(74), and Japan(74). The USA was the most powerful country in comprehensive research strengths with most publications and higher citations. In top 10 countries, the average proportion of independent and internationally-collaborative respectively maked up 71.09% and 28.91%, which indicates that independent research dominates in these countries.

Table2. Top 10 most productive countries from 1975 to 2010

	TP	TC	TC/TP	SP(%)	CP(%)
USA	1947	37550	19.29	89.57	10.43
Canada	155	2519	16.25	68.39	31.61
China	152	1844	12.13	65.13	34.87
Germany	74	1247	16.85	60.81	39.19
Japan	74	753	10.18	75.68	24.32
South Korea	73	443	6.07	67.12	32.88
UK	66	1329	20.14	66.67	33.33
France	59	920	15.59	69.49	30.51
Australia	52	1443	27.75	67.31	32.69
India	52	448	8.62	80.77	19.23
Average				71.09	28.91

TP, total articles; TC, total citations; SP(%), percentage of single-country articles; CP(%), percentage of internationally-collaboration articles

At the country level, 2585 (88.89%) were single-country articles and 323 (11.11%) were international-collaborative articles, which indicated that independent research dominated in these countries/territories (Figure3). Although both single-country and internationally-collaborative articles increased in the past 35 years, the annual proportion of single-country articles decreased from 100% in 1975 to 84.45% in 2010, and the annual proportion of internationally-collaborative articles increased from 0% in 1975 to 15.55% in 2010. This change demonstrated that academic institutions and researchers of non point source research gradually became more internationally connected.

The relative importance of individual countries/territories in the collaboration network were measured, using UCINET6 network analytical software. UCINET6 identified a core group consisting of main countries/territories which hold relatively important positions in the international collaboration network (Figure4). The size of the corresponding nodes represents the amount of internationally-collaborative articles, and the thickness of the links represents the strength of cooperation between the two countries. According to the size of the network nodes, USA, China and Canada carried out a lot of international cooperation with numerous collaboration articles; based on the the thickness of the links, the USA located the core position in the collaboration network, closely cooperating with Canada, China ,South Korea, and UK. The primary cooperation countries/territories of China were USA, Canada and Netherlands.

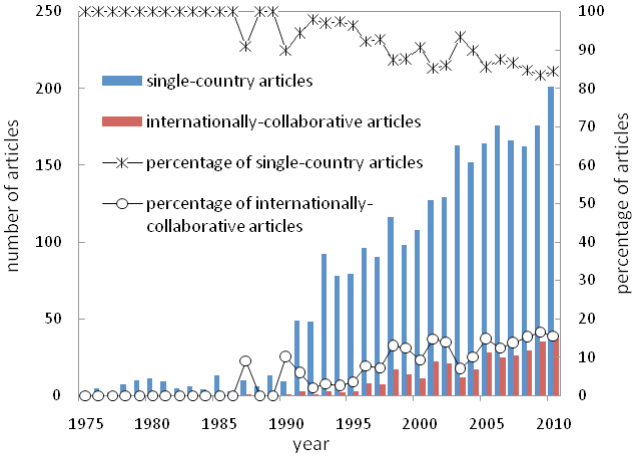

Figure3. Characteristics by year of cooperation publications

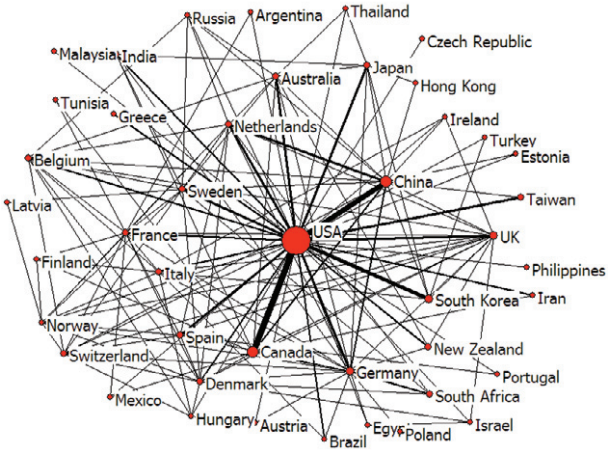

Figure 4. the cooperation of the major countries/territories

3.5 Keywords Analysis

A keywords analysis was used to reveal the trend in non point source research and identify hot topics that draw most research efforts[12]. The keywords analysis in our study adopted author keywords as statistics objects. A total of 2141 articles included the author keywords. All author keywords were statistically analyzed, and the 30 most frequent keywords within each 5-year intervals during 1991-2010 were presented in Table3.

It was obvious that the primary research interests in non point source was water quality. “Water quality” ranked 2nd consistently during 1991-2010. Both “point source” and “non point source” are responsible for the poor water quality [14], but non point source pollution is the leading reason for water quality deterioration [15]. “Eutrophication”, which was caused by non point pollution, has become a serious pollution problem [16]. “Phosphorus” and “nitrogen”,

"nutrients", "sediment", "nitrate", and "pesticides" were the important non point pollutants. As the main indexes, "phosphorus" and "nitrogen" ranked 4th and 7th respectively during 1991-2010. The rank and percentage of "nutrients" rose from 19th (0.43) in 1996-2000 to 5th (1.19%) in 2006-2010. This significant growth indicated that nutrients attracted more and more attention during the past 15 years.

Non point source research would focus on applying new techniques and methods. "GIS" ranked 5th during 1991-2010, which was increasingly used in detecting temporal and spatial changes of non point source pollution load [17]. Additionally, some methods and principles, such as "watershed management", "modeling", "simulation", "monitoring", and "remote sensing" are the most popular research methods in non point source rearch. Remarkably, as the most common model, "best management practices (BMPs)", "soil and water assessment tool (SWAT)", and "watershed modeling" showed a significant increasing trend during 1996-2010. SWAT was developed to assess the impact of management on water supplies and nonpoint source pollution in watersheds and large river basins[18].

"Agriculture", "land use", "runoff", and "pollution" were proved to be the major influencing factor of non point source pollution. Agricultural nonpoint source runoff may result in massive discharges of pesticides, suspended sediments, and fertilizers into estuarine habitats adjacent to agricultural areas or downstream from agricultural watersheds[19]. "Land use" had a consistently high ranking during the past two decades, and ranked 18th during 1991-2010. Notoriously, urbanization caused land use change and transformed natural landscapes into anthropogenic impervious surfaces [20], and urban expansion was a major driving force increasing non point source pollution [21].

Table3. Frequency of top 30 author keywords in articles

	TP	R (%)			
		1991-1995	1996-2000	2001-2005	2006-2010
non point source pollution	811	1(8.45)	1(7.39)	1(7.13)	1(5.6)
water quality	453	2(4.32)	2(3.87)	2(4.27)	2(3.12)
non point source	175	3(2.35)	3(1.56)	5(1.44)	5(1.19)
phosphorus	170	5(1.88)	5(1.48)	6(1.34)	4(1.31)
GIS	161	4(2.25)	4(1.52)	4(1.55)	11(0.87)
watershed management	143	12(0.94)	9(0.91)	3(1.7)	9(0.93)
nitrogen	134	6(1.31)	6(1.35)	7(1.1)	8(0.95)
best management practices (BMPs) ↑	125	9(1.03)	12(0.78)	14(0.76)	3(1.33)
nutrients↑	121	9(1.03)	19(0.43)	8(1.07)	5(1.19)
modeling	120	6(1.31)	7(1.04)	8(1.07)	12(0.83)
sediment	104	9(1.03)	15(0.65)	11(0.89)	10(0.89)
eutrophication	102	8(1.13)	9(0.91)	11(0.89)	15(0.71)
runoff	94	17(0.56)	13(0.7)	10(0.92)	13(0.73)
agriculture	82	14(0.66)	9(0.91)	13(0.81)	20(0.46)
nitrate	82	14(0.66)	13(0.7)	15(0.71)	16(0.64)
groundwater	66	19(0.47)	7(1.04)	19(0.5)	22(0.36)
watershed	65	629(0)	16(0.61)	17(0.6)	18(0.56)
land use	63	21(0.38)	18(0.48)	20(0.47)	17(0.6)
soil and water assessment tool (SWAT) ↑	62	101(0.09)	112(0.09)	26(0.29)	7(0.97)
total maximum daily load (TMDL)↑	60	629(0)	112(0.09)	18(0.58)	13(0.73)
pesticides	49	51(0.19)	19(0.43)	15(0.71)	37(0.2)
erosion	48	13(0.85)	17(0.56)	21(0.45)	43(0.18)
simulation	48	14(0.66)	19(0.43)	55(0.16)	19(0.5)
hydrology	38	28(0.28)	29(0.3)	26(0.29)	23(0.34)
wetlands	38	21(0.38)	19(0.43)	23(0.31)	29(0.24)
pollution	36	19(0.47)	25(0.35)	32(0.26)	28(0.26)
watershed modeling↑	35	28(0.28)	112(0.09)	26(0.29)	21(0.38)
monitoring	34	629(0)	25(0.35)	26(0.29)	24(0.3)
surface runoff	29	629(0)	38(0.22)	23(0.31)	29(0.24)
remote sensing	29	21(0.38)	45(0.17)	46(0.18)	26(0.28)

TP, total articles; R(%),rank and percentage of author keywords; ↑ ,growth trend

4. Conclusions

According to the bibliometric analysis, significant non point source research trend were obtained. In total, there were 2924 articles published during 1975-2010. With the development of SCI and SSCI, non point source research continually grew and started to go up significantly in 1990. "Environmental sciences and ecology", "water resources", "engineering", "agriculture", and "ecology" were the five most central subject categories. The most active journal was "*Journal of the American Water Resources Association*", and 37.86% of the total articles resided in the 10 most productive journals. The main study area distributed in North America and Europe with strong scientific research capabilities, followed by East Asia. 79 countries/territories participated in non point source research. The USA was the largest contributor with the most articles and international cooperation. Independent research dominated in various

countries, and internationall-collaborative research increased gradually. The keywords analysis confirmed that water quality, non point pollutions, and watershed were the hottest issues of non point source research; “GIS”, “watershed management”, “modeling”, “simulation”, “monitoring”, and “remote sensing” were the most popular research methods; and “agriculture”, “land use”, “runoff”, and “pollution” were the leading causes of non point source pollution.

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