Available online at www.sciencedirect.com
ScienceDirect
Journal of Informetrics 2 (2008) 65–74
Journal of INFORMETRICS
An International Journal
www.elsevier.com/locate/joi

Global scientific production on GIS research by bibliometric analysis from 1997 to 2006

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Received 11 June 2007; received in revised form 23 September 2007; accepted 8 October 2007

Abstract

A bibliometric analysis was applied in this work to evaluate global scientific production of geographic information system (GIS) papers from 1997 to 2006 in any journal of all the subject categories of the Science Citation Index compiled by Institute for Scientific Information (ISI), Philadelphia, USA. 'GIS' and 'geographic information system' were used as keywords to search parts of titles, abstracts, or keywords. The published output analysis showed that GIS research steadily increased over the past 10 years and the annual paper production in 2006 was about three times 1997s paper production. There are clear distinctions among author keywords used in publications from the five most productive countries (USA, UK, Canada, Germany and China) in GIS research. Bibliometric methods could quantitatively characterize the development of global scientific production in a specific research field. The analytical results eventually provide several key findings.

Keywords: GIS; Bibliometric; Research trend; Author keyword analysis

1. Introduction

Geographic information systems are computerized systems for the storage, retrieval, manipulation, analysis and display of geographically referenced data. When it was first developed in the 1960s, the GIS were primarily used in the public sector. The industry then made vigorous progress in the 1970s and 1980s, during which the United States has played a leading role. Since then, research on both methodology and application of GIS has grown rapidly all over the world and GIS have now developed into an ever increasingly important and versatile tool for many different research fields covering natural, social, medical sciences and engineering (Anselin, 1995; Guisan & Zimmermann, 2000; Ohashi et al., 1996).

Despite increasing interest, there have been few attempts at gathering systematic data on the global scientific production of GIS research. A common research tool is the bibliometric method which has already been widely applied in scientific production and research-trend studies in many disciplines of science and engineering (Almind & Ingwersen, 1997; Cronin, 2001; Moed, Debruin, & Vanleeuwen, 1995). Furthermore, the Science Citation Index (SCI), provided by the Institute for Scientific Information (ISI) Web of Science databases, is the most important and frequently used source database for the review of scientific achievement in all research fields (Bayer & Folger, 1966; Kostoff, 2000).

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doi:10.1016/j.joi.2007.10.001

Conventional bibliometric methods generally evaluate the research trend by investigating the publication outputs of different countries (Rahman, Haque, & Fukui, 2005), research institutes (Rajendram, Lewison, & Preedy, 2006), journals (Dannenberg, 1985), and research fields (Davis & Gonzalez, 2003) or by doing the citation analysis (Chiu & Ho, 2005). However, focusing on the changes in the quantities of citations or publications alone may not be adequate to provide a clear indication of the developing trends or future orientation of a research field. Information based on the content of studies, such as source titles, author keywords, keyword plus and abstracts should be introduced in research-trend studies. Arrue and Lopez (1991) first attempted to evaluate the growth pattern of conservation tillage research based primarily on abstracts published on Soils and Fertilizers. Qin (2000) used keywords plus to investigate the development of antibiotic resistance research. The keyword plus in the SCI database supplied additional search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes (Garfield, 1990).

The purpose of this study is to analyze the SCI scientific literatures on GIS from the last 10 years by using two different methods, the conventional bibliometric method, and an innovative author keyword analysis method, which specifically focuses on the comparison of the five most productive countries, providing insights into the development of GIS research throughout the world. The study can facilitate the discussion of future development of GIS research and help guide researchers in this dynamically developing field.

2. Methods and materials

The data was based on the database of the SCI published by and subscribed from the ISI, Web of Science (now Thomson Scientific), Philadelphia, PA, USA. The analysis of publication papers was extracted following a literature search using the online version of SCI. 'GIS' and 'geographic information system' were used as the keywords to search parts of titles, abstracts, or keywords. The total number of papers related to GIS research in the ISI web database published between 1997 and 2006 was 9849. These were published with 11 document types with the distribution analysis. There were 9109 paper articles comprising 92% of the total production, followed by reviews (223; 2.3%), book reviews (185; 1.9%), meeting abstracts (139; 1.4%), editorial materials (126; 1.3%), news items (28; 0.28%), corrections (20; 0.20%), letters (9; 0.09%), software reviews (5; 0.05%), reprints (4; 0.04%), and addition corrections (1; 0.01%).

Publications originating from England, Scotland, North Ireland, and Wales were grouped under the UK heading. The impact factor (IF) of a journal was determined for each document as reported in the year 2005 ISI, Journal Citation Reports (JCR), which is the latest data available. Citation counts of all the papers were obtained on April 16th, 2007 when the SCI search process for this study was conducted. Collaboration type was determined by author description, where 'independent' was assigned if no collaboration was presented. 'International collaboration' was assigned if it was co-signed with researchers from more than one country.

The emphasis of the discussion below was to describe global scientific production on GIS research from following five aspects:

- Growth of output during 1997–2006.
- Distribution of output in subject categories and journals identified by ISI.
- Citation analysis of the research output.
- Research output analysis of different countries.
- Distribution of Author keywords analysis.

This effort will provide a current view of the mainstream research on GIS all over the world, as well as clues to the impacts of the topics.

3. Results and discussion

3.1. Publication outputs

The scientific output between 1997 and 2006 is shown in Table 1. The annual number of publications, the number of cited references, the number of pages, the number of journals, and the number of producing countries devoted to GIS research all increased considerably. Only 565 papers relating to GIS were published in 1997, while during the

Table 1
Characteristics by year of publication outputs

PY	P	PG	PG/P	NR	NR/P	AU	AU/P	J	P/J	Country
1997	565	6578	12	15,661	28	1573	3	282	2.0	52
1998	680	7393	11	17,742	26	1931	3	323	2.1	68
1999	697	8416	12	20,520	29	2002	3	333	2.1	68
2000	839	10,545	13	25,118	30	2481	3	394	2.1	71
2001	886	10,763	12	27,614	31	2729	3	420	2.1	76
2002	916	11,240	12	28,363	31	2872	3	423	2.2	75
2003	1132	14,125	12	36,590	32	3592	3	465	2.4	82
2004	1224	14,955	12	40,711	33	4121	3	550	2.2	84
2005	1411	17,750	13	48,451	34	5128	4	630	2.2	101
2006	1499	19,308	13	54,361	36	5360	4	624	2.4	96

P: number of publications; PG: page count; NR: cited reference count; AU, J, and Country: number of authors, journals, and countries; PG/P, NR/P, and AU/P: average of pages, references, and authors in a paper; P/J: average of papers in a journal.

past 10 years, the number of publication rose 1.50-fold in 2005 and 1.65-fold in 2006. The global production outputs in GIS research increased at the annual average growth rate of approximately 11.5% for past decade, and the total paper publication showed two obvious peaks in 2000 and 2003, with the increase rates of 20.4% and 23.6% compared to the previous year, respectively. The average article lengths fluctuated slightly, with an overall average length of 12 pages. The mean number of references per article also varied over the years, from 28 references per article in 1997 to a maximum of 36 in 2006. In Table 1, the distinct increase in the number of publication outputs and the references indicate the stable growth and communication in the field of GIS related research during the past decade.

Furthermore, a significant correlation was found between the yearly cumulative number of publications and the year, as displayed in Fig. 1. The cumulative progression was represented by two exponential models. The plot of the data revealed a much higher coefficient of determinations in the two 5-period: 1997–2002 ($r2 = 0.999$) and 2002–2006 ($r2 = 0.999$). The publication growth rate in the later period was even higher compared to that of period 1997–2002. Therefore, it can be concluded that the number of scientific papers on the topic of GIS is still growing at a high rate. Based on the exponential model during 2002–2006, it can also be calculated that, in 2012, the number of scientific papers on the topic of GIS will be twice of the number of publications in 2006.

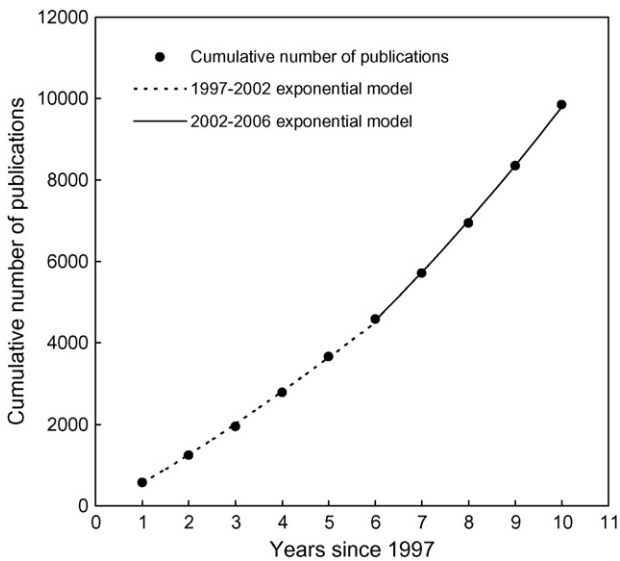

Fig. 1. Cumulative number of publications by year.

3.2. Subject categories and journals

In the research topic of GIS, there was great diversity, including 202 subject categories identified by ISI during the past 10 years. The three most common categories were Environmental Sciences, Geosciences and Multidisciplinary, and Ecology. As the use of statistics in any scientific discipline can be considered a key element in evaluating its degree of maturity (Palmer, Sese, & Montano, 2005), the results provided a current view of the research emphasis of this topic. GIS was mostly present in the subject category of Environmental Sciences and Geosciences related fields. However, the proportion of scientific articles per category exhibited some variation during the time period covered. A distinct decrease of ranking appeared in three categories: Information Science and Library Science, Imaging Science and Photographic Technology, and Remote Sensing. The growth rate of yearly publications within these three categories slowed down in recent years. Besides, the publication quantities in both the subject categories of Water Resources and Environmental Studies had such a significant growth that they ranked 5th and 7th, respectively, during the later 5-year period of 2002–2006, which can hardly reach top-10 in 1997.

In total, 9849 papers referring to GIS were published in a diverse variety of 1918 journals belong to all 202 subject categories above. There are 10 journals with more than 100 published papers related to GIS research during the last 10 years. Approximately 15% of the total GIS research publications reside in these 10 core journals, whereas the remainders reside in the other 1908 journals. *International Journal of Geographical Information Science* ranked first with 281 (2.9%) published papers and *International Journal of Remote Sensing* ranked second with 185 (1.87%) publications.

3.3. Citation analysis

A common bibliometric indicator, citations per publication, was ordinarily used to assess the impact relative to the entire field (Herbertz & MullerHill, 1995). The total citation count was obtained from SCI, Web of Science, on April 10, 2007 when the SCI search process for this study was conducted, and this showed the total number of times that a particular paper had been cited by all journals listed in the database. The title of the most cited paper since it was published to 2006 of each year in the time span was *Predictive habitat distribution models in ecology* written by Guisan, A. and Zimmermann, N.E., then, received by *Ecological Modeling* in 2000 which has been cited by 455 times in all. Among the top 10 most cited papers, the USA contributed 6 of them, followed by UK, which produced or participated in 3 articles; Canada and Austria with 2 articles, and, Switzerland, China, and Sweden with 1 article each. It is worth mentioning that papers related to medical fields had a relatively higher number of citations than many other scientific fields. Nevertheless, there still existed a bias on citation analysis due to differences of the publication year. It must be pointed out that the number of citations in single article was highly correlated with the length of time since its publication (Chiu & Ho, 2005; Marx & Cardona, 2003). As can be seen in Fig. 2, the average number of times cited per paper for all the 9849 articles evidently increases along with the number of years since its publication. Therefore, papers are cited if it is difficult to compare the number of times they were published in different years.

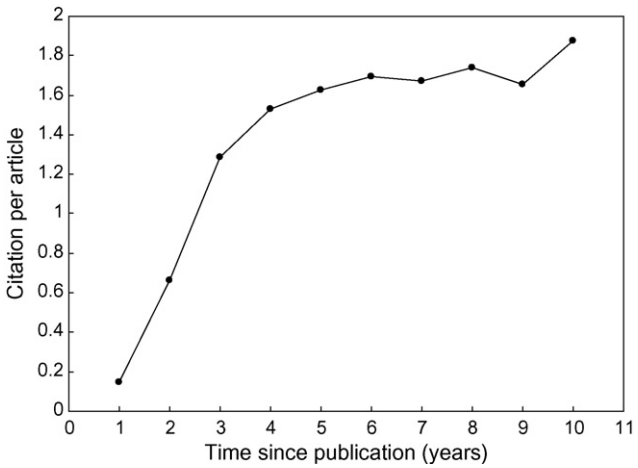

Fig. 2. Citation per publication by paper life.

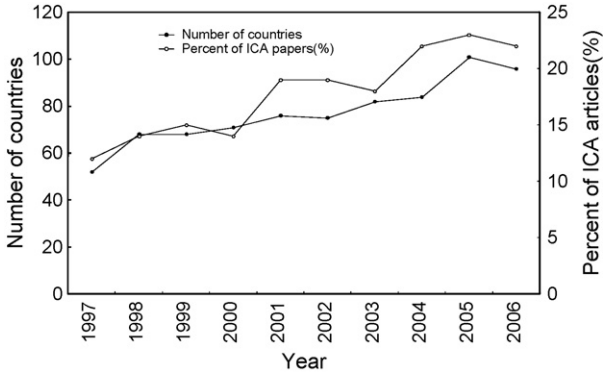

Fig. 3. Relationships among the number of countries, ICA share of world publications and year.

To adjust for that, instead of using just times cited since publication, Chiu and Ho (2005) applied the new index TC3 (times cited before year 3) to assess the visibility or impact of articles, because they found that the frequency of being cited is highest on the third full year since its publication. Afterwards, it decreases. In this study, as documents published after 2005 would not have TC3 values, we only discuss the 6939 articles from 1997 to 2004 for citation tracking. It was found that their TC3 were 22,367 in total with a frequency from 0 to 146 and an average of 3.22.

3.4. International collaboration

There were 212 papers without author address information on the ISI Web of Science. Of the 9849 papers, 7773 (79%) were independent publications and 1864 (19%) were international co-authorship (ICA). The apparent increasing trend in the number of countries worldwide participating in GIS research can be noted in Fig. 3. International cooperation, playing an ever-growing role in contemporary scientific research, can usually manifest itself in internationally co-authored papers tracked by bibliometric tool (Schubert & Braun, 1990). The increasing trend of ICA share of world publication was somewhat in accordance with the trend of the number of countries (Fig. 3). In general, ICA papers were more prevalent in recent years than in earlier years. Using 5-year intervals to minimize the year-to-year fluctuations, the percentages of articles with ICA were 15% and 21% for the periods 1997–2001 and 2002–2006, respectively. It indicated that GIS research had become more globally connected. The increased case of communication in a technologically connected world contributed to the increasing collaboration. However, half of the total papers from 103 countries were

Table 2
Top 15 most productive countries from 1997 to 2006

Country/territory	TP	R (%)	SP	R (%)	CP	R (%)	CP%
USA	3893	1 (40)	3102	1 (40)	791	1 (42)	20
UK	1037	2 (11)	694	2 (8.9)	343	2 (18)	33
Canada	619	3 (6.3)	390	3 (5)	229	4 (12)	37
Germany	531	4 (5.4)	304	4 (3.9)	227	5 (12)	43
China	527	5 (5.4)	276	5 (3.6)	251	3 (13)	48
Australia	412	6 (4.2)	265	6 (3.4)	147	7 (7.9)	36
Italy	362	7 (3.7)	235	8 (3)	127	9 (6.8)	35
Netherlands	330	8 (3.4)	138	11 (1.8)	192	6 (10)	58
Japan	329	9 (3.3)	239	7 (3.1)	90	11 (4.8)	27
France	276	10 (2.8)	135	12 (1.7)	141	8 (7.6)	51
Spain	252	11 (2.6)	164	10 (2.1)	88	13 (4.7)	35
India	249	12 (2.5)	205	9 (2.6)	44	20 (2.4)	18
Switzerland	182	13 (1.8)	74	18 (0.95)	108	10 (5.8)	59
Sweden	159	14 (1.6)	96	16 (1.2)	63	15 (3.4)	40
Belgium	154	15 (1.6)	69	22 (0.89)	85	14 (4.6)	55

SP: single country publication output; CP: international collaboration publication output; CP%: the percent of international collaboration publication output for one country; R (%): the rank and percentage of the country in the study field.

Table 3
Frequency of author keywords used in publications—top 25

Author keywords	1997-2006		1997-2001		2002-2006	
	P	R (%)	P	R (%)	P	R (%)
GIS	2360	1(24)	740	1 (20)	1620	1 (26)
Remote sensing	435	2 (4.4)	154	2 (4.2)	281	2 (4.5)
Geographic information system	395	3(4)	150	3 (4.1)	245	3 (4)
Geographic information systems	370	4(3.8)	145	4 (4)	225	4 (3.6)
Spatial analysis	136	5 (1.4)	43	6 (1.2)	93	5 (1.5)
Geographical information systems	119	6 (1.2)	55	5 (1.5)	64	12 (1)
Land use↑	118	7 (1.2)	30	13 (0.82)	88	6 (1.4)
Geographical information system	116	8 (1.2)	39	8 (1.1)	77	7 (1.2)
Geographic information systems (GIS)	112	9 (1.1)	36	9 (0.98)	76	8 (1.2)
GPS	99	10 (1)	33	11 (0.9)	66	10 (1.1)
Geographic information system (GIS)	96	11 (1)	30	13 (0.82)	66	10 (1.1)
Modeling	94	12 (1)	35	10 (0.95)	59	13 (1)
Water quality	89	13 (0.9)	30	13 (0.82)	59	13 (1)
Conservation↑	85	14 (0.86)	17	38 (0.46)	68	9 (1.1)
Modelling	81	15 (0.82)	25	18 (0.68)	56	15 (0.91)
Mapping	78	16 (0.79)	27	17 (0.74)	51	16 (0.82)
Landscape ecology↓	76	17 (0.77)	43	6 (1.2)	33	33 (0.53)
Epidemiology	70	18 (0.71)	25	18 (0.68)	45	20 (0.73)
Climate change↓	69	19 (0.7)	32	12 (0.87)	37	27 (0.6)
Logistic regression↑	68	20 (0.69)	18	35 (0.49)	50	17 (0.81)
Soil erosion↑	68	20 (0.69)	19	32 (0.52)	49	18 (0.79)
Landscape	68	20 (0.69)	24	21 (0.65)	44	21 (0.71)
Biodiversity↓	67	23(0.68)	18	35 (0.49)	49	18 (0.79)
Risk assessment	67	23 (0.68)	23	23 (0.63)	44	21 (0.71)
Simulation↓	65	25 (0.66)	30	13 (0.82)	35	31 (0.57)

P: publications in the study period; R (%): the rank and percentage of the author keyword; ↓ Percentage went down significantly over time; ↑ percentage went down significantly over time

P: publications in the study period; R (%): the rank and percentage of the author keyword; ↓: percentage went down significantly over time; ↑: percentage went down significantly over time.

signed by at least one foreign author, which may also reveal a low ability to independently conduct research. Some researchers probably still need more help from researchers of developed countries to produce more research in this field.

Table 2 shows the top 15 countries ranked by number of publications, including the number of single country articles and internationally collaborated articles. Eight countries with the 10 highest Country GDP (USA, Japan, Germany, China, the UK, France, Italy, and Canada) also ranked as the 10 most productive countries which published papers related to GIS research. Moreover, the eight countries are also productive in independent papers, which included 5375 (69% of all 7773 independent papers). Domination in publication is not surprising from mainstream countries since

Table 4
Frequency of author keywords used in publications from five most productive country during last decade

World		USA		UK		Canada		Germany		China	
Keywords	P (%)	Keywords	P (%)	Keywords	P (%)	Keywords	P (%)	Keywords	P (%)	Keywords	P (%)
Remote sensing	435 (4.4)	Remote sensing	158 (4.1)	Remote sensing	27 (2.6)	Remote sensing	20 (3.2)	Remote sensing	22 (4.1)	Remote sensing	43 (8.3)
Spatial analysis	136 (1.4)	Modeling	68 (1.7)	Modelling	25 (2.4)	Watershed	14 (2.3)	Germany	12 (2.3)	China	39 (7.5)
Land use	118 (1.2)	Spatial analysis	63 (1.6)	Conservation	16 (1.5)	Canada	13 (2.1)	Simulation	10 (1.9)	Spatial distribution	12 (2.3)
GPS	99 (1)	Water quality	60 (1.5)	Land use	16 (1.5)	Climate change	11 (1.8)	Land use	9 (1.7)	Soil erosion	11 (2.1)
Modeling	94 (0.95)	GPS	46 (1.2)	Mapping	16 (1.5)	Spatial analysis	10 (1.6)	Climate change	7 (1.3)	Land use	9 (1.7)
Water quality	89 (0.9)	Land use	44 (1.1)	UK	14 (1.4)	DEM	8 (1.3)	Risk assessment	7 (1.3)	GPS	8 (1.5)
Conservation	85 (0.86)	Landscape ecology	41 (1.1)	Climate change	13 (1.3)	Kriging	8 (1.3)	Distribution	6 (1.1)	RS	8 (1.5)
Modeling	81 (0.82)	Landscape	39 (1)	Spatial analysis	13 (1.3)	Modeling	8 (1.3)	Geostatistics	6 (1.1)	Spatial analysis	7 (1.4)
Mapping	78 (0.79)	Watershed management	37 (0.95)	Epidemiology	11 (1.1)	Visualization	8 (1.3)	Precision farming	6 (1.1)	Cellular automata	6 (1.2)
Landscape ecology	76 (0.77)	Agriculture	35 (0.9)	GPS	10 (0.96)	British Columbia	7 (1.1)	X-rays: galaxies	6 (1.1)	Geostatistics	6 (1.2)
Epidemiology	70 (0.71)	Conservation	32 (0.82)	Risk assessment	10 (0.96)	Ontario	7 (1.1)	Decision support	5 (0.94)	Land use change	6 (1.2)
Climate change	69 (0.7)	Runoff	32 (0.82)	Biodiversity	9 (0.87)	Water quality	7 (1.1)	Greater	5 (0.94)	Landslides	6 (1.2)
Logistic regression	68 (0.69)	Habitat	31 (0.8)	Decision support	9 (0.87)	Groundwater	6 (0.97)	Methane	5 (0.94)	Logistic regression	6 (1.2)
Soil erosion	68 (0.69)	Hydrology	29 (0.74)	Exposure assessment	9 (0.87)	Habitat	6 (0.97)	Modelling	5 (0.94)	Beijing	5 (0.97)
Landscape	68 (0.69)	Non-point source pollution	29 (0.74)	Interpolation	9 (0.87)	Land use	6 (0.97)	Monitoring	5 (0.94)	Classification	5 (0.97)

P: publications in the study period from 1997 to 2006; %: the percentage of the author keyword in the total publications of a country.

this pattern has occurred in most scientific fields (Mela, Cimmino, & Ugolini, 1999). To a certain extent, large numbers of research papers from a country are correlated with the high activity and academic level of the country. The USA showed the greatest counts of world publications, being followed only distantly by other countries. It also had the most frequent partners accounting for 40% of the international collaborative articles. To consider with the ICA and T3 index (as believe mentioned), papers with ICA have higher visibility than others. Of the 9849 articles, 5768 (58.6%) papers had a TC3 value. Among them, 1552 articles had an ICA. These articles had an average TC3 of 4.4, while the others by single countries had an average TC3 of 3.8. It would be reasonable to assume that more international collaboration would lead to more output due to the sharing of ideas and workloads.

3.5. Author keyword

In Table 3, author keywords that appeared in the articles from 1997 to 2006 were calculated and ranked by total 10- and 5-year study time periods. Among all 17,700 author keywords used, 13,854 (78%) keywords appeared only once, 1893 (11%) keywords used twice, and 684 (3.9%) keywords appeared three times. The large number of once only used author keywords probably indicates a lack of continuity in research and a wide disparity in research focuses. The most frequently used keyword for all periods was "GIS" as it was also a keyword used in searching in this study. During the entire study period, 'remote sensing', 'spatial analysis', 'land use', and 'GPS' (Global Positioning System) are always the most frequently used author keywords, which indicates that these topics are invariable hotspots in the field of GIS research (have been highlighted in Table 3). Furthermore, it is worth noticing that little has been done before on 'soil erosion', 'biodiversity', 'groundwater', and 'landslide', but articles on these aspects have obviously increased in recent years. The number of papers and percentage of which author keywords including 'decision support' such as 'decision support system', 'spatial decision support system', 'planning decision support', and 'policy decision support', etc. change drastically from "46, 1.2%" in 1997–2006 to "108, 1.7%" in 2002–2006. This indicates that 'decision support system' (DDS) attracted more and more attention during the past 10 years, indicating that these words may be a potential new focus in the future. On the contrary, it is surprising to find that there are several popular topics in the past such as 'landscape ecology', 'climate change', 'runoff' and 'non-point source pollution', etc. that are becoming gradually less significant as noted during our 10-year study period.

For further analysis, author keywords, which were used as search keywords, were eliminated in Table 4. These author keywords are 'GIS', 'geographic information system', 'geographic information systems', 'geographical information systems', 'geographical information system', 'geographic information systems (GIS)', and 'geographic information system (GIS)'. As a result, it can be seen in Table 4 that there are clear distinctions among author keywords used in publications from the five most productive countries in GIS research. According to the global research, almost all the five countries (a little disparity in Germany) found 'remote sensing', 'spatial analysis', 'land use' and 'GPS' (Global Positioning System) to be hotspots in the current field of GIS research. However, totally different from the Global GIS research, and other four countries in Table 4, the United States took a great interest in the GIS application into landscape analysis, while approximate 2.1% GIS related papers of the United States refer to 'landscape' or 'landscape ecology' (Iverson & Prasad, 1998; Moilanen & Hanski, 1998; Roth, Allan, & Erickson, 1996). Except for China, all the other four countries showed great concerns for the GIS modeling research, while in the Europe, they often use 'modelling' as the same meaning (Arnold, Srinivasan, Muttiah, & Williams, 1998; Pebesma & Wesseling, 1998). Moreover, unlike the United States, the other four countries concentrated more attention on the general application of GIS technology and native environments, respectively, for example, the 'British Columbia' and 'Ontario' in Canada, 'Beijing' in China, etc. In comparison with the developed countries, some GIS related research in China is dropping a little behind. The similarity and disparity among different continents needs to be further studied.

4. Conclusions

In this study on GIS-related papers dealing with the SCI, we obtained some significant points on the global research performance throughout the period from 1997 to 2006. In total, 9849 articles were published in 1918 journals listed in 202 subject categories established by ISI. The GIS research presented an upward trend as the paper production increased steadily in the last 10 years, and the annual paper production in 2006 was about three times that of the paper production in 1997. Based on the exponential model during 2002–2006, it can be assumed that, in 2012, the number of scientific papers on the topic of GIS will be twice that of the number of publications in 2006. As the flagship

journal of the GIS-related field, *International Journal of Geographical Information Science* published the most articles. Approximately 15% of the articles that refer to GIS reside in the 10 core journals, whereas the remainder resides in the other 1908 journals. With the study of national research publications in the last 10 years, the increasing trend in the number of countries worldwide participating in GIS research can be easily observed. To a certain extent, large numbers of research papers from a country are correlated with the high activity and academic level of the country. It was notable that the USA, contributing the most independent and international collaborative articles, had the most frequent international partners. Articles with international co-authorship, the number of which is increasing over the years, had higher visibility than others. 'Remote sensing', 'spatial analysis', 'land use', and 'GPS' was the emphasis of GIS research in all study periods. Several author keywords such as 'decision support system', 'decision support', and 'landslide' dramatically increased since 2002, which became the focus in the last few years, and might be a new research direction in the future. There are clear distinctions among author keywords used in publications from the five most productive countries in GIS research. Bibliometric method could quantitatively characterize the development of global scientific production in a specific research field. As GIS has always been thought to be widely useful to humans, more efforts should be taken to further study in these fields.

Acknowledgements

This paper is funded by National Sciences Foundation of China (No. 40701184). We would also like to thank the great help from Prof. Yuh-Shan Ho (Peking University, Beijing).

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