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Technical Note

Research trends on land use changes during 1991–2015: A Bibliometric Analysis

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ABSTRACT

Land use changes, as a practical and advanced space exploration technology, offered a lot of valuable data about the earth surface for global analysis, detailed assessment, environmental monitoring, mapping, change detection, disaster management, and civil and military intelligence. To provide a better understanding of global trends in land use changes research over the past 25 years and offer an informed perspective on future research, a bibliometric analysis of published land use changes research was conducted to evaluate current research trends from various perspectives quantitatively and qualitatively for the period of 1991-2015 based on SCIE&SSCI databases. This study is concentrated on the analysis of scientific outputs, research directions, source journals, author performance and their contribution, the distribution of research countries/territories as well as institutions and their collaboration and temporal trends in keywords usage.

1. Introduction

Land use change, as an important cause of global environmental change as well as an international key research subject ,plays a significant role in comprehensive research of natural and social sciences. Land changes are cumulatively a major driver of global environmental change [1].With the intensification of a series of problems like population growth, food shortages, environmental pollution, climatic differences and so on, studies on land use changes have been strengthened in global change research. A large amount of papers which presented the latest research achievement about land use changes have been published in scientific journals and help the public have a better understanding on land use changes. However, a comprehensive statistical review of the land use change-related research has not been conducted to date. In addition to existing studies, a bibliometric analysis of land use changes research could help evaluate the performance of global land use changes research and indicate potential future research directions .

Bibliometric refers to a research methodology that utilizes quantitative analysis and statistics to describe the research trends of various research fields [2]-[6].The traditional bibliometric methods focused on contents and citation analysis [7]-[11], newly bibliometric analysis developed network analysis which applied to analyze the relationships of keywords, country, research institute and author, including co-word analysis [12]-[13],co-authorship analysis [14],and co-publication analysis [15],etc.In addition, CiteSpace and ArcGIS software have been used to provide a spatial distribution of authors and research institutes [16], [17].Furthermore, a number of indicators were used to analyze researchers' performance on a deeper level, such as CPP(average number of citations per publication)[18], [19],h-index[20] and GIF(the geographical impact factor)[21].

In this research, conventional bibliometric methods are

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associated with newly methods like international collaboration network analysis in order to provide an in-depth analysis of the data. This research aims at reviewing the development of land use changes research over the past 25 years with the analysis of annual publication outputs, research directions, source journals and authors, national and institutional research performance, as well as suggesting global research trends which could serve as a potential guide for future research.

2. Materials and methods

2.1 Material

Publications on land use changes were obtained form the Science Citation Index Expanded(SCIE) and Social Sciences Citation Index(SSCI) databases SCIE and SSCI are the most reliable used sources for bibliometric analysis in a variety of scientific fields[16], [17]."land use chang*", "land cover chang*", "land use/cover chang*" ("chang*" can be "change"," changes" or "land use changing")and"land use monitoring*" were used to search all publications that contained these words in title, abstract, and keywords.The citations of articles used to evaluate authors' academic influences were updated to May 1st, 2016. We subsequently combined all the records and deleted duplicated records. A total number of 16246 articles related to land use changes during 1991-2015 were found in SCIE&SSCI databases.

2.2 Methods

The conventional bibliometric analysis of scientific outputs, journals, authors, countries, institution, and keywords were conducted with the help of Microsoft Excel 2007.We geocoded the affiliations of authors using CiteSpace[22] and plotted the geographic distribution of authors using ArcGIS 10.2 .Meanwhile, Ucient 6 and NetDrew 2.097 [23] were used to visualize a core group of countries in the international collaboration network. Like other bibliometric analyses [16] ,[24] , publications originating from England,Northern Ireland,Scotland,and Wales were grouped into that from the United Kingdom(UK),and publications from Hong Kong were not included in China. Impact factor(IF) of each article was taken from the Journal Citation Report(JCR) published in 2015.In the analysis of international collaboration, the address of authors was identified to determine the collaboration type, single-country/single-institution papers were assigned if the authors' address were from the same country/institution and internationally collaborated papers referred to those whose authors' address were from multiple countries/institutions. Besides that,the keywords which had different forms of spelling but identical meaning were unified into a single keyword.

3. Results and discussion

3.1 Characteristic of publication outputs

As is shown in Fig.1,the amount of land use changes-related publications experienced a remarkable growth in the past 25years with an annual growth rate of 36.5%.Meanwhile,the share of relevant publications of the total records,as an indicator,"standard no. of articles",which was used to compare the number of publications on land use changes research with the total number of publications in the source databases,kept their steady upward trend,which indicating an increasing interest on land use changes research.

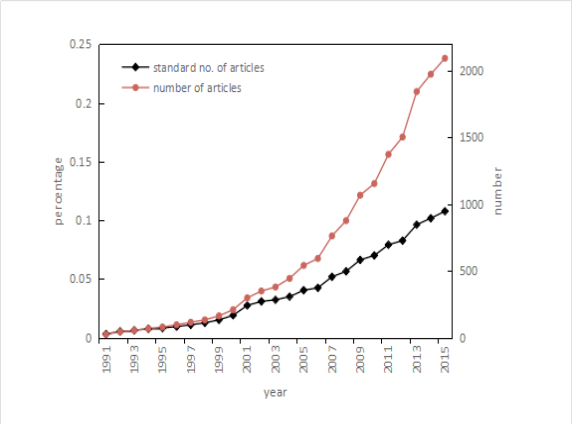

Fig.1 The number and standard number of land use changes-related publications by year

Among the 16246 publications, article(14374) was the dominant document type which accounted for 88.48% of the total publications. Review and proceeding paper toke up small portions of the total with 5.04% and 4.72%,respectively.Obviously the most frequently used language was English (16054),comprising 98.82% of the total publications, followed by Spanish (0.4%), Portuguese(0.23%) and German(0.22%).The characteristics of publication outputs for the period 1991-2015 are listed in Table 1 along with the annual number of publications and the number of authors, cited references, page count, total citation count as well as their average value. The average number of authors increased steadily with slight fluctuation and it was 5.03 in 2015 which was more than twice as many as 2.25 in 1991,indicating the more collaborative activities in land use changes research. In addition, the average number of citations was 24.2 and it appeared three highest

values with 101.98, 98.09 and 81.37 in 1992, 1994 and 2000, suggesting that there were several influential discoveries on land use changes research in these particular year.

Table 1. Characteristics of scientific outputs from 1991 to 2015

PY	TP	NO.AU	NO.AU/TP	NR	NR/TP	PG	PG/TP	TC	TC/TP
1991	24	54	2.25	965	40.21	349	14.54	1086	45.25
1992	44	98	2.23	1274	28.95	611	13.89	4487	101.98
1993	54	135	2.50	1338	24.78	694	12.85	2429	44.98
1994	68	167	2.46	2440	35.88	952	14.00	6670	98.09
1995	79	217	2.75	2431	30.77	966	12.23	3872	49.01
1996	96	247	2.57	3496	36.42	1363	14.20	5850	60.94
1997	115	333	2.90	5264	45.77	1696	14.75	6658	57.90
1998	133	367	2.76	5513	41.45	1838	13.82	7713	57.99
1999	163	486	2.98	7906	48.50	2570	15.77	9011	55.28
2000	209	729	3.49	9222	44.12	2959	14.16	17081	81.73
2001	298	942	3.16	13582	45.58	4156	13.95	18203	61.08
2002	349	1165	3.34	16024	45.91	4979	14.27	23065	66.09
2003	379	1299	3.43	18035	47.59	5550	14.64	21885	57.74
2004	444	1632	3.68	21362	48.11	6471	14.57	22821	51.40
2005	541	2077	3.84	24666	45.59	7588	14.03	24804	45.85
2006	593	2179	3.67	29207	49.25	8176	13.79	21129	35.63
2007	762	3097	4.06	39467	51.79	10051	13.19	28566	37.49
2008	877	3615	4.12	45720	52.13	11470	13.08	32109	36.61
2009	1068	4418	4.14	55828	52.27	13085	12.25	29726	27.83
2010	1155	4897	4.24	64281	55.65	14810	12.82	30381	26.30
2011	1374	6004	4.37	78970	57.47	17813	12.96	28656	20.86
2012	1504	6597	4.39	89210	59.32	19249	12.80	19456	12.94
2013	1845	8482	4.60	110103	59.68	24041	13.03	15821	8.58
2014	1975	9601	4.86	117891	59.69	25959	13.14	8788	4.45
2015	2095	10538	5.03	133015	63.49	28778	13.74	2917	1.39

Note: TP,number of publications;NO.AU,number of authors;NR,cited references;PG,page count;TC,total citation count;NO.AU/TP,NR/TP,PG/TP,and TC/TP,averages of authors,references,pages and citations per article

3.2 Research directions and major journals

In this research, publications (8120) belonging to the research area of environmental sciences ecology covered 49.92% of the total which indicated its important position in land use changes research. Besides, the research on land use changes was mainly focused on geology (2509;15.43%), agriculture(2169;13.34%), water resources (1857;11.42%), physical geography(1405;8.64%) and meteorology atmospheric sciences (1308;8.04%). The total 16246 publications appeared in 1413 journals and the 20 most productive journals are exhibited in **Table 2.** The top 20 or 1.42% of the 1413 journals which accounted for 4166 or 25.64% of the total publications showed a high concentration of land use changes publications in these top journals. There were 506 journals(38.51%) published only one relevant paper and 971(68.72%) journals published less than five papers in all. Obviously Agriculture Ecosystems & Environment published the most papers on land use changes(310),followed by Global Change Biology(298),International Journal of Remote Sensing(270),Land Use Policy(262) and Journal of Hydrology(256).In terms of total citations per paper and Impact Factor,Global Change Biology which aimed to provide a multi-disciplinary forum for work that contributes to our understanding of biological responses and feedbacks in global change with an Impact Factor of 8.708 published a sizable number of highly cited land use changes-related papers(298 articles with 17872 citations).Such journals also including Remote Sensing of Environment (198 articles with 11508 citations) and Ecological

Applications(164 articles with 9405 citations).On average,papers published in these journals have received 30.4 citations, demonstrating the significant influence of these journals in this field.

Table 2. Twenty most active journals in land use changes research

Journal	TP	TC	CPP	IF
AGRICULTURE ECOSYSTEMS & ENVIRONMENT	310	10850	35.00	3.987
GLOBAL CHANGE BIOLOGY	298	17872	59.97	8.708
INTERNATIONAL JOURNAL OF REMOTE SENSING	270	7683	28.46	1.859
LAND USE POLICY	262	4968	18.96	3.095
JOURNAL OF HYDROLOGY	256	8281	32.35	3.912
LANDSCAPE AND URBAN PLANNING	243	5742	23.63	3.659
APPLIED GEOGRAPHY	224	4076	18.20	2.853
FOREST ECOLOGY AND MANAGEMENT	219	6569	30.00	3.153
LANDSCAPE ECOLOGY	210	6435	30.64	3.861
REMOTE SENSING OF ENVIRONMENT	198	11508	58.12	7.769
HYDROLOGICAL PROCESSES	195	5309	27.23	3.353
ENVIRONMENTAL MONITORING AND ASSESSMENT	185	2007	10.85	1.918
ENVIRONMENTAL MANAGEMENT	181	4701	25.97	2.34
BIOLOGICAL CONSERVATION	179	4717	26.35	4.697
PLOS ONE	179	1250	6.98	3.702
CATENA	168	4755	28.30	3.074
ECOLOGICAL APPLICATIONS	164	9405	57.35	5.508
JOURNAL OF ENVIRONMENTAL MANAGEMENT	158	3777	23.91	3.895
CLIMATIC CHANGE	134	4641	34.63	4.61
SCIENCE OF THE TOTAL ENVIRONMENT	133	2092	15.73	4.414

Note: CPP,average number of citations per publication;IF,impact factor

3.3 Author performance

Author performance reflected their contribution to the study of land use changes and the 20 most productive authors are presented in Table 3.Verburg, PH,from Vrije Univ Amsterdam participated in the most papers with the amount of 96,followed by Lavorel,S from Univ Grenoble 1(62),Smith,P from Univ Aberdeen(61), Houghton,RA from Woods Hole Res Ctr(60) and Lambin,EF from Catholic Univ Louvain(57),indicating that these authors took part in the most research activities related to land use changes.

Meanwhile, we summarized the number of papers they published as the first author and the corresponding author as well as the average number of citations per publication. Through comprehensive analysis we found that Hounghton,RA(60 publications with 10140 ctations) from Woods Hole Res Ctr and Lambin,EF(57 publications with 6805 citations) from Catholic Univ Louvain produced relatively high-level achievements in land use changes research both in quantity and quality.Besides,Poesen,J from Katholieke Univ Leuven and Pielke,RA from Univ Colorado owned highly cited land use changes-related publications though they had less papers published as the first author or the corresponding author, implying they ever produced several influential accomplishments in the past 25 years.

Table 3. Twenty most productive authors in land use changes research

Author	Institution	TP	TC	CPP	RP	TC/RP	FCA	TC/FAC
Verburg,PH	Vrije Univ Amsterdam	96	4133	43.05	26(5)	75.54	23(3)	83.78
Lavorel,S	Univ Grenoble 1	62	3799	61.27	7(83)	83.14	6(83)	88.67
Smith,P	Univ Aberdeen	61	3736	61.25	15(11)	91.53	13(11)	104.08
Houghton,RA	Woods Hole Res Ctr	60	10140	169.00	29(2)	149.79	29(2)	149.79
Lambin,EF	Catholic Univ Louvain	57	6805	119.39	15(11)	202.20	14(7)	237.43
Liu,JY	Chinese Acad Sci	53	1745	32.92	21(8)	52.57	9(26)	107.00
Radeloff,VC	Univ Wisconsin	51	1132	22.20	4(299)	49.25	5(139)	53.40
Poesen,J	Katholieke Univ Leuven	48	2083	43.40	3(521)	182.67	1(2680)	429.00
Li,X	Sun Yat Sen Univ	47	1041	22.15	23(7)	30.78	15(5)	39.27
Salvati,L	Italian Council Agr Res & Econ	47	362	7.70	30(1)	8.00	33(1)	7.15
Kuemmerle,T	Humboldt Univ	47	1015	21.60	10(31)	33.50	10(19)	33.50
Fu,BJ	Chinese Acad Sci	46	1087	23.63	27(3)	25.30	8(41)	36.88
Zhang,L	Huazhong Univ Sci & Technol	44	1368	31.09	9(40)	18.11	8(41)	5.00
Wang,Y	Chinese Acad Sci	44	313	7.11	14(13)	7.57	23(3)	6.96
Deng,XZ	Chinese Acad Sci	42	1045	24.88	24(6)	10.42	14(7)	19.14
Pielke,RA	Univ Colorado	41	2464	60.10	6(118)	118.83	6(83)	118.83
Cerri,CC	Univ Sao Paulo	41	1262	30.78	3(521)	19.33	3(455)	22.67
Tian,HQ	Auburn Univ	39	1315	33.72	27(3)	25.85	7(61)	44.00
Ciais,P	Inst Pierre Simon Laplace	38	3230	85.00	3(521)	13.67	3(455)	13.67
Pitman,AJ	Univ New S Wales	36	1279	35.53	17(10)	58.76	11(17)	71.27

Note: FAC,number of papers as the first author;RP,number of papers as the corresponding author;R,ranking among all authors

3.4 International productivity and collaboration

Based on the affiliation information of authors and corresponding authors we acquired the data on international productivity and collaboration. Apart from 73 publications without any author address information, there were 16173 papers published by 163 countries. Among them,10401 papers which were regarded as single-country publications comprised 64% of the total 16173 publications and the rest of them were called internationally-collaborated papers. The 30 most productive countries are displayed in Table 4.As consistent with observation in source journals, the top 30 countries contributed a significant share of publications in land use changes research. These 30countries or 18.4% of the 163 countries, accounted for 9685 or 93.12% of the single-country publications and took up a great portion of the internationally-collaborated publications. It is clear that the USA was the biggest contributor of the land use changes research with 5741 participated papers and held the leading role in the collaborative activities. China ranked second with 2200 papers or approximately two-fifth of the USA's publication output, followed by the UK(1766), Germany(1632), Australia(1072) and Netherlands(890). Other than

the USA, Netherlands and Belgium produced the most high-quality publications with more citations, implying their remarkable achievements on the research of land use changes. In term of the distribution of these countries,16 were from Europe,5 were from Asia,3 were from North America,2 were from Oceania,2 were from South America and 2 were from Africa. As revealed by other bibliometric analyses[25], [26],economic development and thus scientific investment also contributed to this distribution as the seven industrialized nations(G7 group: the USA, the UK, Germany, France, Canada, Japan and Italy) and five major developing countries ("BRICS":Brazil, Russia, China, India and South Africa) were all among countries listed.Among 5772 collaborative publications,4151(72%) were completed by two countries/territories,1019 (18%) were completed by three countries, and only 603(10.5%) were completed by more than three countries/territories. However, we could notice that the internationally-

collaborated papers have received more citations per publication than those single-country publications in most countries, revealing the significance of collaboration in scientific research.

Table 4. Thirty most productive countries/territories in land use changes research

Country	TP	CPP	Single-country			Internationally-Collaborated			MC(A)
			SP	TC/SP	SP%	CP	TC/CP	CP%	
USA	5741	34.36	3368	34.61	32.38	2373	34.01	41.12	China(521)
China	2200	14.45	1133	9.61	10.89	1067	19.59	18.49	USA(521)
UK	1766	30.71	670	25.72	6.44	1096	33.76	18.99	USA(311)
Germany	1632	27.32	558	20.13	5.36	1074	31.05	18.61	USA(293)
Australia	1072	33.11	476	25.22	4.58	596	39.41	10.33	USA(221)
Netherlands	890	38.07	273	39.79	2.62	617	37.31	10.69	UK(161)
Canada	840	30.79	331	21.8	3.18	509	36.63	8.82	USA(241)
France	830	34.11	215	21.66	2.07	615	38.47	10.66	UK(151)
Spain	749	22.68	317	18.47	3.05	432	25.76	7.49	UK(108)
Italy	663	22.37	263	15.89	2.53	400	26.64	6.93	UK(100)
Brazil	659	27.33	211	17.13	2.03	448	32.14	7.76	USA(259)
Switzerland	509	31.14	135	22.93	1.3	374	34.10	6.48	USA(120)
Belgium	450	41.18	120	48.81	1.15	330	38.41	5.72	UK(84)
Japan	424	17.46	184	11.62	1.77	240	21.94	4.16	USA(67)
Sweden	424	40.53	126	18.84	1.21	298	49.69	5.16	Germany(89)
Mexico	354	26.18	144	13.84	1.38	210	34.64	3.64	USA(112)
India	341	15.93	190	8.39	1.83	151	25.41	2.62	USA(70)
New Zealand	308	30.76	121	17.86	1.16	187	39.11	3.24	Australia(58)
Austria	271	35.83	63	27.14	0.61	208	38.47	3.6	Germany(72)
Denmark	252	24.85	65	17.97	0.62	187	27.24	3.24	UK(77)
South Africa	219	27.26	85	13.49	0.82	134	36.00	2.32	USA(44)
Finland	213	33.58	77	18.68	0.74	136	42.01	2.36	UK(45)
Argentina	204	39.56	84	16.52	0.81	120	55.69	2.08	USA(70)
Turkey	201	8.82	169	7.34	1.62	32	16.66	0.55	USA(14)
Norway	188	39.62	55	21.62	0.53	133	47.07	2.3	UK(49)
Portugal	180	21.62	63	10.7	0.61	117	27.50	2.03	UK(32)
Indonesia	178	18.55	24	15.5	0.23	154	19.03	2.67	Germany(42)
Kenya	175	24.18	23	12.87	0.22	152	25.89	2.63	USA(57)
Czech Republic	164	18.01	73	7.59	0.7	91	26.36	1.58	Germany(37)
Greece	132	15.64	69	12.43	0.66	63	19.16	1.09	UK(19)

Note:SP,number of single-country papers;CP,number of internationally-collaborated papers;MC,major cooperator of the country

Network centrality measures the relative importance of nodes within networks and could be used as an indicator of a country/territory's position within the network[16].The core international collaboration network is displayed in Fig.2,in which the thickness of each link represents the intensity of collaboration and the size of each node represents the number of total publications. The USA which as the major cooperative partner of 14 other countries took the central position in collaborative activities of land use changes research. Also, it can not be neglect that 10 of 15 other European countries had most cooperation with the UK due to the impact of European Union.

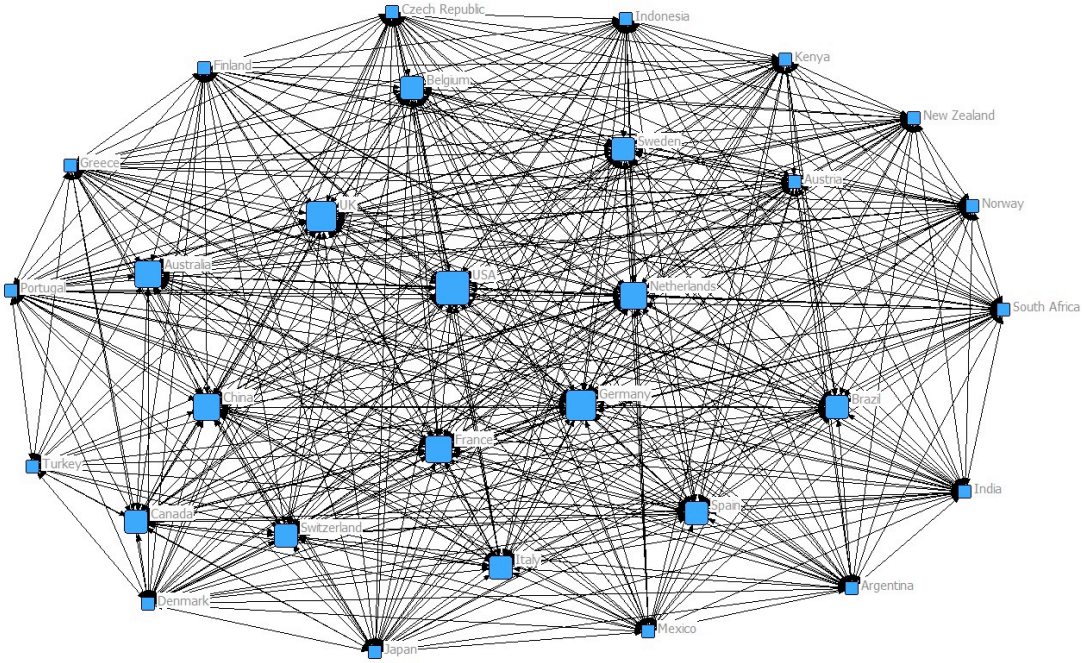

Fig 2. National collaboration network of the 30 most central countries

According to author affiliations, there were 8735 institutions participated in relevant research in the past 25 years and the top 20 productive institutions are presented in Table 5.Chinese Acad Sci ranked first with 1072 total publications, followed by Univ Wisconsin(287),Beijing Normal Univ(241),Univ Maryland(238),US Geol Survey(217) and US Forest Serv(212). The ranking result might be biased by the fact that organizations such as Chinese Acad Sci and USGS are in fact institutions that consist of branches in many cities. Among the 20 institutions,12 of them were from the USA,4 were from China and the rest were from Netherlands, Mexico and Belgium. Furthermore, it can be revealed from the number of single-institution and inter-institutional collaborated publications that institutions tended to cooperate with others in order to make full use of their advantages.

3.5 Keywords analysis

Author keyword, provided as a summary of each articles' content, can be analyzed to gain insights into research trends and frontiers[10].We chose the 12992 publications with explicit author keywords as analysis object.19575 or 73.6% of the total keywords appeared in publications were used only once, revealing the wide relationship between land use changes research and other research fields. The keywords which were used more than ten times (916) were present in mainstream

Table 5. Twenty most active institutions in land use changes research

Institution	TP	%	SI	CI
Chinese Acad Sci	1072	2.67	193	879
Univ Wisconsin	287	0.71	53	234
Beijing Normal Univ	241	0.60	33	208
Univ Maryland	238	0.59	34	204
US Geol Survey	217	0.54	41	176
US Forest Serv	212	0.53	16	196
Colorado State Univ	209	0.52	22	187
Univ Calif Berkeley	192	0.48	39	153
Michigan State Univ	184	0.46	34	150
Wageningen Univ	172	0.43	15	157
Purdue Univ	162	0.40	32	130
Univ Nacl Autonoma Mexico	162	0.40	40	122
CSIC	161	0.40	26	135
Univ Minnesota	155	0.39	29	126
Katholieke Univ Leuven	148	0.37	20	128
Stanford Univ	148	0.37	16	132
Univ Florida	148	0.37	34	114
Univ Chinese Acad Sci	146	0.36	1	145
Univ Illinois	145	0.36	25	120
Vrije Univ Amsterdam	143	0.36	19	124

Note: SI, number of single-institution papers; CI, number of collaborated-institutions papers

research and occupied 3.45% of the total keywords. The 30 most frequently used keywords are presented in table 6 with the whole 25-year period was divided into five 5-year periods in order to evaluate the temporal evolution of the land use changes research. To better identify the change of hot issues in research, we marked the variation trend of certain keywords with relatively high fluctuation in ranking and listed the emerging keywords with sharp increase in frequency in the past 25 years. Without the consideration of the search words including “land use change”, ”land use”, ”land cover change”, ”land cover” and ”land use/cover change”, ”climate change” was the most frequently used keyword which drew the most attention of researchers in the past 25 years for land use is a significant influential factor of climate change. Land use change impacts regional and global climate through the surface-energy budget, as well as through the carbon cycle [27].”Remote sensing” and “GIS”, as significant research methods which provided effective tools for data processing, ranked 2th and 4th with 739 and 425 publications respectively. Meanwhile, the emerging keyword “Landsat” enjoyed a large rank advancement because of its rapid technical progress in providing higher-quality research data. These technologies had been applied effectively in numerous studies[28]-[31].“Agriculture”, ”urbanization” and “change detection” accessed to much attention in research, indicating the popular interest in studying the process of land use changes. ”Modeling” was the major research method in various aspects of land use changes studies, including statistical models, driving force models, simulation models, feedback models and so on. From a specific perspective, studies on ”biodiversity”, ”soil organic carbon”, ”soil erosion”, ”soil organic matter”, ”landscape”, ”water quality”, “runoff”, ”greenhouse gas emissions” showed that researchers paid close attention to ecological and environmental effects of land use changes, especially in terms of ecosystem, soil, vegetation, hydrology and climate change. Furthermore, ”deforestation”, ”conservation” and “sustainability” which drew constant attention of researchers in the past 25 years ranked 6th,19th and 25th,respectively,revealing that the purpose of study is protect natural environment and seek sustainable development. The steady growth in ranking of “China” showed that China was more attractive to land use changes research for its rich land resource and complicated issues in land use. The trends of changes in ranking and the emerging condition of keywords can reflect the hot issues in relevant research fields. It is worth noting that “biofuel” ,“bioenergy”, ”ecosystem services” and “landscape metrics” which as the emerging keywords have become critical areas of growing concern worldwide. A lot of work on “ecosystem services” reflected the significance of studies on comprehensive ecological environment effects and the prevalent use of ”biofuel” and “bioenergy” indicate the ever-increasing interest in renewable energy sources. The emerging models of “SWAT (Soil and Water Assessment Tool)” and “CA (cellular automata)” and emerging index of “landscape metrics” and “NDVI” obtained effective application and received great attention. In contrast, ”soil erosion” and “erosion” were also frequently used keywords though their ranking decreased in these years

4. Conclusion

In this paper, we obtained an explicit insight into the global trends in land use changes research over the period 1991-2015 based on a bibliometric analysis of certain aspects. The result suggests that the number of scientific output exploded with an annual growth rate of 36.5%, faster than SCIE&SSCI publications. Environmental sciences ecology, geology, agriculture, water resources and physical geography were major research directions in land use changes research. Agriculture Ecosystems & Environment published the most papers, followed by Global Change Biology, International Journal of Remote Sensing, Land Use Policy and Journal of Hydrology. In terms of author performance, Verburg, PH, Lavorel, S ,Smith, P, Houghton, RA and Lambin, EF participated in the most papers, in which Lambin, EF and Houghton, RA produced most high-quality papers. The USA contributed the largest number of single-country and internationally collaborated publications, followed by China, the UK, Germany and Australia. Netherlands and Sweden produced the most high-quality papers with more citations, implying their remarkable research achievements. Meanwhile, internationally collaborated publications have received more citations per paper than those single-country publications. Network analysis suggested that the USA took the central position in collaborative activities and most European countries tended to cooperate with the UK. Chinese Acad Sci, Univ Wisconsin, Beijing Normal Univ, Univ Maryland and US Geol Survey were the most productive institutions.

Through keywords analysis, we found that “climate change” was the most hot .

Table 6. Fifty frequently used keywords in land use changes research

Keywords	TP	TP(R)				
		2011-2015	2006-2010	2001-2005	1996-2000	1991-1995
land use change	3065	1621(1)	879(1)	416(1)	130(1)	19(1)
land use	1125	558(3)	328(2)	167(2)	60(2)	12(2)
climate change	972	600(2)	248(3)	84(6)	28(3)	12(2)
remote sensing	735	366(4)	242(4)	101(3)	23(5)	3(6)
land cover change	715	357(5)	236(5)	99(4)	20(6)	3(6)
deforestation	572	262(6)	184(6)	91(5)	28(3)	7(4)
GIS↓	426	194(9)	147(7)	64(7)	18(7)	3(6)
biodiversity	357	200(7)	101(11)	44(9)	11(11)	1(35)
agriculture	355	194(9)	104(9)	37(12)	18(7)	2(15)
urbanization↑	346	198(8)	103(10)	37(12)	7(28)	1(35)
land use/cover change	307	160(14)	111(8)	35(14)	1(307)	
land cover	303	165(13)	86(12)	44(9)	6(36)	2(15)
china↑	293	169(12)	81(13)	34(15)	8(23)	1(35)
biofuel*↑	273	146(15)	58(19)		1(307)	
ecosystem services*↑	246	191(11)	51(21)	4(244)		
carbon sequestration	243	127(18)	68(14)	43(11)	5(48)	
Modeling	220	92(23)	67(15)	50(8)	10(15)	1(35)
change detection	215	138(16)	61(18)	13(54)	2(147)	1(35)
conservation	213	118(20)	67(15)	21(23)	4(64)	3(6)
soil organic carbon	212	127(18)	63(17)	20(28)	2(147)	
Landsat*↑	189	134(17)	42(27)	13(54)		
soil erosion↓	180	90(24)	50(23)	26(19)	11(11)	3(6)
water quality	168	78(28)	51(21)	23(21)	14(9)	2(15)
carbon	166	74(30)	52(20)	29(17)	9(19)	2(15)
sustainability	165	106(21)	38(30)	13(54)	7(28)	1(35)
nitrogen	165	71(31)	50(23)	34(15)	10(15)	
runoff	152	85(25)	39(28)	18(35)	9(19)	1(35)
global change	151	82(26)	33(36)	16(44)	14(9)	6(5)
afforestation	142	71(31)	47(26)	20(28)	3(93)	1(35)
bioenergy*↑	134	106(21)	27(54)	1(949)		
soil carbon	132	70(33)	31(43)	25(20)	5(48)	1(35)
landscape metrics*↑	125	81(27)	35(34)	9(94)		
fragmentation	121	60(42)	39(28)	19(32)	2(147)	1(35)
grassland	113	58(44)	32(40)	17(38)	5(48)	1(35)
biomass	111	59(43)	29(45)	17(38)	6(36)	
amazon	110	42(63)	36(32)	28(18)	3(93)	1(35)
hydrology	110	42(63)	36(32)	21(23)	10(15)	1(35)
phosphorus	109	51(47)	31(43)	21(23)	6(36)	
Brazil	109	44(58)	32(40)	21(23)	11(11)	1(35)
soil organic matter	106	55(46)	27(54)	16(44)	8(23)	
Mexico	106	30(116)	50(23)	18(35)	8(23)	
NDVI*	105	62(41)	33(36)	10(79)		
SWAT*	104	78(28)	16(116)	10(79)		
uncertainty	101	65(36)	25(62)	8(102)	2(147)	1(35)
disturbance	101	47(53)	29(45)	20(28)	3(93)	2(15)
landscape	100	39(77)	38(30)	18(35)	5(48)	
erosion↓	100	38(80)	28(50)	22(22)	10(15)	2(15)
cellular automata*↑	97	65(36)	22(74)	10(79)		
greenhouse gas emissions↑	95	69(34)	22(74)	3(343)		1(35)
reforestation	95	49(51)	29(45)	12(62)	5(48)	

Note:*,the emerging keyword;(R),ranking of the keyword in the specific period;↑,the upward trend in rank;↓,the downward trend in rank

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References

Turner BL, Lambin EF and Reenberg A, The emergence of land change science for global environmental change and sustainability. Proc Natl Acad Sci USA, Vol. 104, Issue 52, 2007, pp. 20666–20671.

Hsieh,W.H., Chiu,W.T., Lee,Y.S., and Ho,Y.S., Bibliometric analysis of patent ductus arteriosus treatments. Scientometrics, Vol. 60, Issue 2, 2004, pp. 105–115.

Chen,S.R.,Chiu,W.T.,and Ho,Y.S.,Asthma in children: mapping the literature by bibliometric analysis. Revue Francaise D Allergologie Et D Immunologie Clinique, Vol. 45, Issue 6, 2005, pp. 442–446.

Ho,Y.S.,Bibliometric analysis of adsorption technology in environmental science. Journal of Environmental Protection Science, Vol. 1, Issue 1, 2007, pp. 1–11.

Tsay,M.,A bibliometric analysis and comparison on three information science journals: JASIST,IPM,JOD,1998–

2008. Scientometrics, Vol. 89, Issue , 2011, pp. 591–606.

Liu,X.J., Zhan,F.B., Hong,S., Niu,B.B., and Liu,Y.L., A bibliometric study of earthquake research: 1900–2010. Scientometrics, Vol. 92, Issue 3, 2012, pp. 747–765.

Van Raan,A.,Advanced bibliometric methods for the evaluation of universities. Scientometrics, Vol. 45, Issue 3, 1999, pp. 417–423.

Almeida-Filho,N.,Kawachi,I.,Pellegrini,A.,and Dachs,J.N.W.,Research on health inequalities in Latin America and the Caribbean:bibliometric analysis (1971–2000) and descriptive content analysis (1971–1995). American Journal of Public Health, Vol. 93, Issue 12, 2003, pp. 2037–2043.

Grossi,F.,Belvedere,O., and Rosso,R., Geography of clinical cancer research publications from 1995 to 1999. European Journal of Cancer, Vol. 39, Issue 1, 2003, pp. 106–111.

Chiu,W.T., and Ho,Y.S., Bibliometric analysis of tsunami research. Scientometrics, Vol. 73, Issue 1, 2007, pp. 3–17.

Abramo,G., D'Angelo,C.A., and Viel,F., The field-standardized average impact of national research systems compared to world average: the case of Italy. Scientometrics, Vol. 88, Issue 2, 2011, pp. 599–615.

Zhao,L.M.,and Zhang,Q.P.,Mapping knowledge domains of Chinese digital library research output,1994–2010. Scientometrics, Vol. 89, Issue 1, 2011, pp. 51–87.

Ding,Y., Chowdhury,G.G., and Foo,S., Bibliometric cartography of information retrieval research by using co-word analysis. Information Processing and Management, Vol. 37, Issue 6, 2001, pp. 817–842.

Glanzel,W.,Science in Scandinavia: a bibliometric approach. Scientometrics, Vol. 48, Issue 2, 2000, pp. 121–150.

Schmoch,U., and Schubert,T., Are international co-publications an indicator for quality of scientific research? Scientometrics, Vol. 74, Issue 3, 2008, pp. 361–377.

Liu,X.J., Zhang,L.A., and Hong,S., Global biodiversity research during 1900–2009: a bibliometric analysis. Biodiversity and Conservation, Vol. 20, Issue 4, 2011, pp. 807–826.

Wang,H.J., He,Q.Q., Liu,X.J., Zhuang,Y.H., and Hong,S., Global urbanization research from 1991 to 2009: a systematic research review. Landscape and Urban Planning, Vol. 104, Issue 3–4, 2012, pp. 299–309.

Van Raan,A.F.J.,Comparison of the Hirsch-index with standard bibliometric indicators and with peer judgment for 147 chemistry research groups. Scientometrics, Vol. 67, Issue 3, 2006, pp. 491–502.

Skram,U., Larsen,B., Ingwersen,P., and Viby-Mogensen,J., Scandinavian research in anaesthesiology 1981–2000: visibility and impact in EU and world context. Acta Anaesthesiologica Scandinavica, Vol. 48, Issue 8, 2004, pp. 1006–1013.

Hirsch,J.E., An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United States of America, Vol. 102, Issue 46, 2005, pp. 16569–16572.

Zhuang,Y., Liu,X., Nguyen,T., He,Q., and Hong,S., Global remote sensing research trends during 1991–2010: A bibliometric analysis. Scientometrics, Vol. 96, Issue 1, 2012, pp. 203–219.

Chen,C.M., Searching for intellectual turning points: Progressive knowledge domain visualization. Proceedings of the National Academy of Sciences of the United States of America, Vol. 101, Issue , 2004, pp. 5303–5310.

Borgatti,S.P., Everett,M.G., and Freeman,L.C., Ucinet for windows:Software for social network analysis. Harvard.MA: Analytic Technologies, 2002.

Ho,Y.S., Wang,M.H., and Yu,T.C., A bibliometric analysis of the performance of Water Research. Scientometrics, Vol. 84, Issue 3, 2010, pp. 813–820.

Tarkowski,S.M., Environmental health research in Europe - bibliometric analysis. European Journal of Public Health, Vol. 17, Issue suppl 1, 2007, pp. 14–18.

Xie,S.D., Zhang,J., and Ho,Y.S., Assessment of world aerosol research trends by bibliometricanalysis. Scientometrics, Vol. 77, Issue 1, 2008, pp. 113–130.

Pielke,R.A., Marland,G., Betts,R.A., Chase,T.N., Eastman,J.L., Niles,J.O., Niyogi,D.D.S., and Running,S.W., The influence of land-use change and landscape dynamics on the climate system: relevance to climate-change policy beyond the radiative effect of greenhouse gases. Philosophical Transactions of The Royal Society OF London Series A-Mathematical Physical and Engineering Sciences, Vol. 360, Issue 1797, 2002, pp. 1705-1719.

Liu,J.Y., Liu,M.L., Tian, H.Q.,Zhuang, D.F.,Zhang, Z.X.,Zhang, W.,Tang,X.M., and Deng,X.Z., Spatial and temporal patterns of China's cropland during 1990-2000: An analysis based on Landsat TM data. Remote Sensing of Environment, Vol. 98, Issue 4, 2005, pp. 442-456.

Masek,J.G., Vermote,E.F., Saleous,N.E., Wolfe,R., Hall,F.G., Huemmrich,K.F., Gao,F., Kutler,J., and Lim,T.K., A Landsat surface reflectance dataset for North America,1990-2000. Ieee Geoscience and Remote SENSING Letters, Vol. 3, Issue 1, 2006, pp. 68-72.

Shalaby,A. and Tateishi,R., Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. Applied Geography, Vol. 27, Issue 1, 2007, pp. 28-41.

Dewan,A.M. and Yamaguchi,Y., Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. Applied Geography, Vol. 29, Issue 3, 2009, pp. 390-401.