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Bibliometric analysis of global environmental assessment research in a 20-year period

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ABSTRACT

Based on the samples of 113,468 publications on environmental assessment (EA) from the past 20 years, we used a bibliometric analysis to study the literature in terms of trends of growth, subject categories and journals, international collaboration, geographic distribution of publications, and scientific research issues. By applying thresholds to network centralities, a core group of countries can be distinguished as part of the international collaboration network. A frequently used keywords analysis found that the priority in assessment would gradually change from project environmental impact assessment (EIA) to strategic environmental assessment (SEA). Decision-theoretic approaches (i.e., environmental indicator selection, life cycle assessment, etc.), along with new technologies and methods (i.e., the geographic information system and modeling) have been widely applied in the EA research field over the past 20 years. Hot spots such as "biodiversity" and "climate change" have been emphasized in current EA research, a trend that will likely continue in the future. The h-index has been used to evaluate the research quality among countries all over the world, while the improvement of developing countries' EA systems is becoming a popular research topic. Our study reveals patterns in scientific outputs and academic collaborations and serves as an alternative and innovative way of revealing global research trends in the EA research field.

Introduction

Over the last two decades, more and more human environments face challenges due to rapid global urbanization and population growth, especially in certain developing countries (e.g., China and some Southeast Asian countries). Environmental assessment (EA) has been emerging in this context, which is the process of estimating and evaluating the significant short-term and long-term effects of a program or project on the quality of its location's environment, is of increasing public concern, particularly since this process involves identifying ways to minimize, mitigate, or eliminate these effects and/or compensate for their impact. Other processes, such as environmental impact assessment (EIA) and strategic environmental assessment (SEA), are prepared on the basis of an EA. EIA is widely known to be the assessment of the possible impact (positive or negative) of a proposed project on the environment, considering natural, social, and economic aspects (Mondal and Rashmi, 2010). An EIA regime was first determined in legal form in the USA in1969 and was then introduced to legislations of many other countries and organizations. SEA is considered to be increasingly important in current EA research and represents a programmatic EIA process that is applied to policies, plans, or programs (Al-Abdulghani et al., 2013). Thus, the targets of SEA are different from traditional EIA objectives (e.g., specific projects), while they have been widely applied by both developed and developing countries to confront increasing complexity behind and around current environmental development and decision-making processes derived from the new forms of proactive intervention in more strategic contexts. Comparing to traditional EIA for projects, new impact assessment tools, inherently adaptable to more strategic, and often incremental, levels of decision-making are therefore needed in building policy and planning, which outcome could largely influence project planning and design. Different EA methods have long been recognized as important tools that can help to develop policy reviews, ecosystems protections, and sustainable development aids in the contemporary world. Thus, it is of urgent importance to understand the global trends of EA research fields that are concerned with sustaining human life.

Bibliometrics refers to the research methodology employed in library and information sciences, which utilizes quantitative analysis and statistics to describe the distribution patterns of articles within a given topic, field, institution, or country. Many investigators have recently used these methods in global trends studies of specific fields (Vergidis et al., 2005; Falagas et al., 2006; Kumari, 2006). Bibliometric methods have been applied to assess the scientific outputs or research patterns of authors, journals, countries, and institutes and to identify and quantify international cooperation (Abramo et al., 2011; Chiu and

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Ho, 2007; Ho et al., 2010). For example, in order to analyze the global trends of research productivity in tropical medicine, Falagas et al. (2006) studied the contributions of different world regions to the published research of leading tropical medicine journals during the period of 1995 to 2003. Similarly, Rajendram et al. (2006) used statistic methods to describe the worldwide alcohol-related research from 1992 to 2003. An assumption is made in these studies that the number of research publications of a country in a certain scientific subfield reflects its commitment to the state of science and is a reasonable indicator of the country's Research and Development efforts in that field. However, traditional bibliometric analysis in scientific research fields has two universal deficiencies. First, the original data are usually insufficient, as many studies only select a limited number of journals or categories to represent global research trends related to a given topic (Klein and Hage, 2006; Mela and Cimmino, 1998). Second, changes in the number of citations or publication counts within certain countries and organizations cannot completely represent the development trends or future orientations of that research field (Arrue and Lopez, 1991). Thus, additional quantitative information related to topics and geophysical distributions of the research itself should be introduced into any bibliometric study of research trends (Chuang et al., 2007; Li et al., 2009; Liu et al., 2011; Wang et al., 2013). It has been shown that some newly developed bibliometric analysis provides a spatial distribution of authors and the country/institution collaboration network (Liu et al., 2011). Recently, a new index, the geographic impact factor (GIF), was constructed to evaluate the academic geographic influence of authors in a specific scientific field during a certain period (Zhuang et al., 2012).

In this study, we attempt to use bibliometric methods to quantitatively and qualitatively study the global research trends of EA-related research. Common research tools utilized by bibliometric practitioners include the Science Citation Index (SCI) and Social Science Citation Index (SSCI), which are searchable databases of publications that are maintained by the Institute for Scientific Information (ISI). Keywords may be input into the SCI and SSCI, and the output can be used to determine the impact of authors, institutes, countries, etc. in a particular discipline. The data presented in this work represent the contributions of the major regions of the world to research productivity, published during a 20-year period in all the SCI and SSCI journals within the field of EA-related research. The aims of this study were to reveal underlying patterns in scientific outputs, characteristics of international collaboration, and author distribution of EA-research; to establish the medium- and long-term strategies of these fields; and to develop priority strategies for the future.

Data source and methodology

The methodology used in this research was similar to recent bibliometric studies from our collaborators (Chuang et al., 2007; Wang et al., 2013). Data were obtained from the online version of the ISI Web of Science: SCI (Science Citation Index). "Environment* 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 articles from 1993 to 2012 that contained these words in the title, abstract, or keywords list. We elected to drop any 2013 articles from our search because some of the latest publications from 2013 may not have been uploaded to the online database by the time of our data collection. In total, 135,426 publications met the selection criteria. Upon further examination, only 113,468 of these publications (83.8%) were categorized as "articles" and used for further analysis as relevant citable items in this study.

Downloaded information from each article included the following: names of authors, contact address, title, year of publication, keywords, subject categories, names of publishing journals, and times cited for each year. The records were downloaded into spreadsheet software, and additional programming was manually performed regarding the number of authors, country of origin of the collaborators, and impact factors of the publishing journals (Zhuang et al., 2012). Impact factors were taken from the *Journal Citation Report* (JCR) published in 2012. The h-indexes related to total citations were calculated for all countries with more than 50 articles during the selected period. The h-index is defined by the h of total N papers with *at least* h citations each while the other (N-h) papers have h citations each (Bar-Ilan, 2008; Hirsch, 2005). To be specific, the h-index for an author or a country is the number h of papers among an author or a country's number of publications (Np) that have at least h citations each. The collaboration type was identified through the address of each author, as "independent" was assigned to this field if no collaboration was present while "international collaboration" was assigned if the paper was cosigned by researchers from more than one country.

For the purposes of the study, we classified the various countries into eight world regions: Europe, the United States of America (USA), Asia (excluding China), North America (excluding the USA), Oceania, South America, China, and Africa. This classification is based on a combination of geographic, economic, and scientific criteria (United Nations Statistical Yearbook, 2004). The number of published articles was used as indexes of research productivity. The emphasis of this work was to determine the characteristics of scientific articles based on research activity trends (e.g., categories, journals, and country distributions) and trends in the research subjects (e.g., author keywords).

Results and discussion

Article characteristics

Several publication output characteristics of current EA research during the time span of 1993 to 2012 are summarized in Table 1. As the table shows, the annual number of articles, the average number of authors, and the annual number of countries and journals publishing EA-related literature increased significantly. Only 1607 articles were published in 1993 but rose to 13,072 in 2011 and 14,557 in 2012. In addition, while the average number of authors per EA article was 3.0 for 1993, this number steadily increased to 4.7 by 2012. The article with the most authors (125), published in *Atmospheric Chemistry and Physics*, 2011, provided the results of the European Aerosol Cloud Climate and Air Quality Interactions project (EUCAARI), which can be used in both European and global environmental assessments of the impact of aerosol as well as corresponding abatement strategies (Kulmala et al., 2011). The annual number of countries that participated in EA research increased rapidly during the selected period, beginning with a minimum of 81 countries in 1993 and rising to a maximum of 163 in 2012. Along with the development of ISI, an increasing number of journals published research papers related to environmental assessment. The average article lengths fluctuated slightly, with an overall average of 11.1 pages. Twenty-seven references were cited per article in 1993, compared to 45 references per article in 2012, an obvious increase over the course of this 20-year period.

The cumulative progression in the number of articles from 1993 to 2012 is further illustrated by Fig. 1. By utilizing a logistic regression model, we simulated the growth pattern based on the cumulative publications in each year from the 1993 as the first year, which can be expressed as follows (Reed and Pearl, 1927):

$$P = 1610.8 \times e^{0.1106t}, \quad (1)$$

where P is the annual number of articles and t is the number of years after 1993 (for $t = 0, 1, 2, \ldots, 19$). Due to the high coefficients of determination ($r^2 = 0.979$) of Eq. (1), the world publications related to EA research could be estimated using this statistical model. The fit of the logistic model showed that yearly publications experienced distinct growth, marked by an increased rate, and the inflexion of the logistic model would probably occur in 2023 (29.8 years after 1993), which indicates that the current growth rate could be sustained, at least in the next 10 years. Based on the model of our study period, it can be calculated that, in 2019, the annual number of scientific papers on the topic of