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Two geographic information system-linked bibliometric indices to quantify the knowledge flow: A case of Qinghai-Tibet plateau research

Wang Xuemei [a,b], Li Xin [c], Ma Mingguo [d,*], Zhang Zhiqiang [b]

[a] Southwest University Library, Beibei 400715, China
[b] Lanzhou Library, Chinese Academy of Sciences, Lanzhou, 730000, China
[c] Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
[d] School of Geographical Sciences, Southwest University, Beibei 400715, China

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ABSTRACT

Cited information is an important pathway of scientific influence. It can reflect the knowledge flows among research units. This study develops two new bibliometric indices—the Citation Flow Index (CFI) and the Normalized Citation Flow Index (NCFI)—to measure knowledge flows based on scientific literature citations. The CFI measures the interactions of knowledge flows among different research units. The NCFI measures the number of papers that a research unit cited and the number of papers by a research unit that are cited. The newly developed indices were tested on a country-wide scale using the literature on the Qinghai-Tibet Plateau (QTP) as an example. The results indicate that the worldwide flow of knowledge on the QTP can be quantitatively measured and spatially displayed. Additionally, the annual NCFI change trend is analyzed for each research unit.

1. Introduction

Scientific literature is one of the most important types of knowledge, and the citation of such literature is a basic form of the flow of knowledge. Against the backdrop of the rapid development of computer and Internet technologies, knowledge flow has become faster, more convenient, and internationalized (Storper, 2000). Researchers can index and download scientific literature more easily, which promotes citation. The citation of scientific literature is a bidirectional flow. Researchers cite and are cited by others. That is, a researcher demonstrates the influence of other researchers by citing their publications, which is knowledge inflow. The influence of the researcher on other researchers can also be demonstrated when papers are cited by them, which is knowledge outflow. This knowledge export through citation reflects the true value of research (Cummings, 2003). The knowledge flow expressed by citation occurs primarily among scientists. This flow can be measured at group, institution, or country levels, i.e., among collaborating researchers and researchers who contribute to more than one field (Gupta & Govindarajan, 2000; Chen, Ibekwe-SanJuan, & Hou, 2010; Ho, 2013).

2. Problem statement

The quantification of the knowledge flows among different research units (e.g. countries, regions, cities, institutions) is very important, as it can enhance understanding of a research unit's original contributions of some research results to other research units. Nowadays assessment agencies or authorities place a string emphasis on the influence of original contributions. Therefore accurate and informative indices are needed to quantitatively estimate the influence of original contributions.

The influence of original contributions is normally reflected by citation. Therefore the knowledge flow of citation is one form of information flow, and can be quantified by various bibliometric indices (Vinkler, 2010). The most common indices mainly focus on the amounts of the knowledge outflow (Garfield, 1998; Schubert & Glänzel, 2006; Hassan & Haddawy, 2013). But knowledge flow also includes knowledge inflow, and few researchers have measured these two phenomena simultaneously. To quantify knowledge flow, this study develops two bibliometric indices which are linked to geographic information systems (GIS). These two indices have the potential to provide information about knowledge inflow and outflow at the same time. The study presented here addresses the question: Can scientific knowledge inflow and outflow be spatially quantified by bibliometric indices at the same time?

3. Literature review

Several bibliometric indices have been described in the literature. The impact factor (IF) is a measure that reflects the average number of references to recent articles published in journals, in particular, academic journals (Garfield, 1998). Although the IF should indicate the likelihood of an article being cited, the IF indicates the average citation level of a journal, which does not express the true citation level of an individual paper. Other indices similar to the IF have been designed for

* Corresponding author.
E-mail address: mmg@lzb.ac.cn (M. Mingguo).

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citation assessment at the journal level. For example, the Gini concentration coefficient was designed as a measure of the unevenness of citation distribution (Stegmann & Grohmann, 2001). The number of times that a paper is cited is more meaningful than the IF. For a scientist, both the IF and the total number of times that all of his or her articles have been cited are typically used to assess the influence of a scientist's work. The *h*-index attempts to measure both the productivity and citation impact of the published body of work of a scientist or scholar (Hirsch, 2005). It is intended to measure simultaneously the quality and quantity of an individual's scientific research output, and was widely applied after being introduced. Since then, several variants of the *h*-index have been presented (Bornmann, Mutz, & Daniel, 2008; Schreiber, 2008).

The indices noted above involve the quantified estimation of one direction of knowledge flow: outflow. In contrast, Schubert & Glänzel (2006) used matrixes of international co-authorship, cross-references, and cross-citations to present knowledge inflow and outflow at the country level. The International Scholarly Impact of Scientific Research (ISISR) index is designed to measure the ability of a country to compete by calculating the citations made to the country's authors or researchers from outside the country in a given subject area. This represents a quantified estimation of the single direction of knowledge inflow (Hassan & Haddawy, 2013). Additionally, the distance factor is used to measure the spatial distribution pattern of bidirectional knowledge flow. Spatial distance is calculated among citing and cited papers based on the GoogleMap application programming interface (API) and Yahoo! PlaceFinder (Ahlgren et al., 2013; Wu, 2013).

4. Methods

4.1. Data and study area

The Qinghai-Tibet Plateau (QTP; 25° ~ 40°N, 74° ~ 104°E) is the world's highest and largest plateau, with an area of 2.6 million km^2 (Fig. 1). The average elevation is over 4500 m, and all 14 of the world's 8000-m and higher peaks are found in this region; it is occasionally referred to as "the roof of the world" (Qiu, 2008). It is surrounded by massive mountains. The Qinghai-Tibet Railway, Qinghai-Tibet Road, Qingkang Road, and Sichuan-Tibet Road are the main traffic corridors that connect the eastern or western regions. There are 1091 lakes of more than 1.0 km^2 in the area, which account for 49.4% of the total area of lakes in China (Jiang & Huang, 2004). Because the QTP responds to climate and environmental change rapidly (Schwalb et al., 2008), it has long been considered one of the world's "hot spots". A large number of scientific articles have been published on this region, which increases the significance of this study.

This study focuses on the international knowledge flow within the QTP literature. Therefore, the emphasis of the calculations and analysis is placed on international publications. The Web of Science maintains the world's most comprehensive, multidisciplinary, bibliographic database of research information. This database exhibits better representation when used to search scientific papers and analyze the status and trends of specific subject areas. Scientific papers, including articles, reviews, and letters, are indexed in the Science Citation Index Expanded (SCIE). This index was searched with the title keyword query "Tibet* or Xizang or Qinghai or Qinghaitibetan or Kunlun or Hengduan or Himalayas or Qilian or Gangdise or Muztagata or (Muztag Ata) or Everest". This rendered 7448 papers published from 1900 to 2012 that focus on the QTP. There were 31,445 papers published from 2000 to 2012 that cited these papers. The total number of citations was 92,468.

4.2. Citation Flow Index

Citation Flow Index (CFI) measures the knowledge flow of literature citations. This index can be described by the following formula:

$$CFI = \frac{C_{a\to b} - C_{b\to a}}{C_{a\to b} + C_{b\to a}} \quad (2)$$

where $C_{a\to b}$ denotes the number of studies by research unit *a* cited by research unit *b* in the given research areas during a given time period. Conversely, $C_{b\to a}$ indicates the number of times that research unit *b* is cited by research unit *a* in the given research areas during a given time period. To explain the meaning of the CFI, a test was performed. The $C_{a\to b}$ ranges from 0 to 1000 times at the step of 10 times, and $C_{b\to a}$ ranges from 1000 to 0 times at the step of 10 times. Then, the CFI

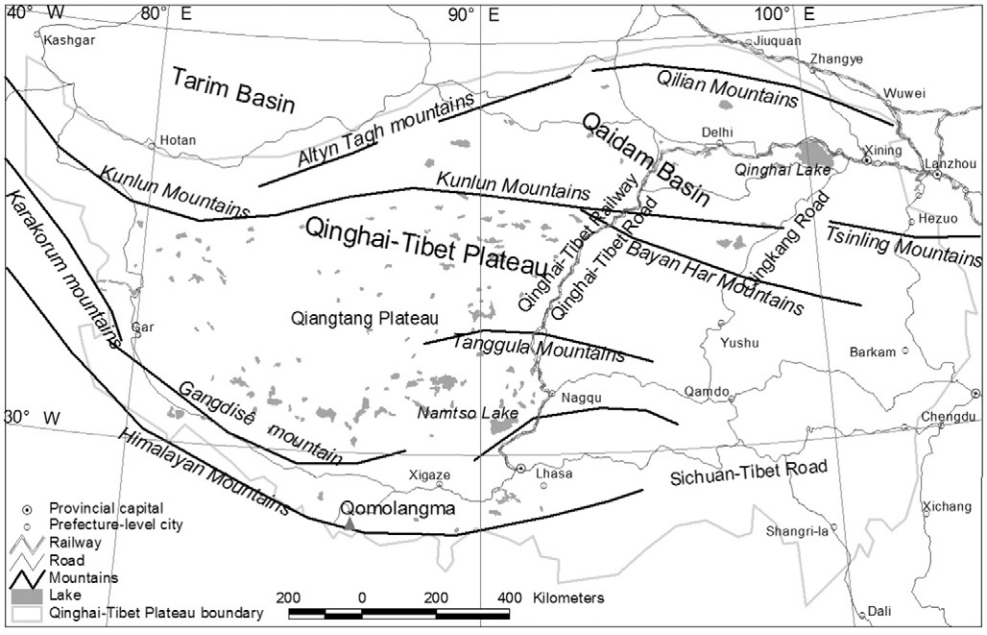

Fig. 1. Study area.