Research trends on geographic information systems and academic libraries: A bibliometric approach using Web of Science

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ABSTRACT
This study employs the Web of Science database to conduct a bibliometric analysis of scientific output pertaining to geographic data and geographic information systems (GIS) in university libraries. The principal objective is to identify the current trends and topics within the scientific literature on this subject. The research encompasses a total of 455 documents published between 1993 and 2023. The results indicate a sustained growth in the literature from 1993 to 2007, followed by a slight decrease from 2008 to the present. China and the United States are identified as the primary contributors to scientific production in this field. Keyword co-occurrence analysis delineates the predominant thematic areas, emphasizing the relationships between GIS and academic libraries, although the frequency of the term "GIS" is notably higher. These findings are compared with previous research, providing a more comprehensive view of patterns and trends in scientific production. The results offer a deeper understanding of the role of GIS in academic library management and point out opportunities for future research in the field.

Keywords: geographic information systems, GIS, academic libraries, bibliometric study, Web of Science

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1. INTRODUCTION

University libraries serve as repositories for academic and research knowledge and, thus, bear the responsibility of spearheading the development and implementation of novel services. Geographic data, in addition to serving as a valuable research tool, represent a significant component of any library's collections, reflecting not only the resources available for consultation but also the tangible outcomes of research projects conducted by the university. In this context, Granell and Aguilar Moreno (2013) posit that the quantity of georeferenced data currently being generated presents a potential opportunity for libraries and information units to serve as intermediaries for this type of data and their users. The management of geographic data from digital tools has facilitated the development of information services designed to preserve documentary and cultural heritage. This synergy has enhanced the visibility of a diverse array of collections, including historical maps, photographic archives, and engravings, as well as academic publications. This has facilitated access to information and enabled the management of an ever-growing community of users. In this regard, Vardakosta and Kapidakis (2012) conducted an analysis of the various types of digital

geospatial data in academic libraries worldwide. Their findings revealed that 136 university libraries offer geographic information services via their websites, although structured policies for the treatment of such information have yet to be established.

Geographic information systems (GIS) are digital tools for the management, storage, and visualization of geographic data, playing an essential role in decision-making in a variety of contexts. As Galeano Castillo (2017) notes, these systems represent a specialized category in geographic information management, distinguishing themselves from traditional information management platforms. They offer advanced capabilities, including data manipulation and query, analysis, and visualization. As defined by Carmona and Monsalve (2004), a GIS is comprised of three essential elements: hardware, software, and procedures. These elements are meticulously designed to support the capture, management, manipulation, analysis, modeling, and graphic representation of spatially referenced data. GIS tools manage geographic data in various layers. The application of GIS has expanded beyond its traditional domain in the field of geographic sciences, successfully extending to urban planning, medicine, biology, and the social sciences.

Geographic information systems are technologies that have been incorporated into the management of libraries, playing a pivotal role in the administration of collections, user management, data storage, and the visualization of documentation. As asserted by Aguilar Moreno and Granell Canut (2015), there is a notable inclination towards the aggregation of data pertaining to GIS software, the establishment of directories comprising links to data sources, and the curation of digital resources pertaining

to collections, publications, congresses, and other pertinent materials. A number of bibliometric studies have examined the convergence of GIS and libraries. Fish and Piekielek (2016) examine the expansion of geospatial services provided by academic libraries to facilitate teaching and research. The researchers employed a bibliometric analysis encompassing searches across 95 departments representing diverse academic areas, including hospitality management, religious studies, veterinary science, biology, and other university disciplines. This approach enabled them to identify trends in the utilization of GIS and collaboration with librarians as "change agents" to facilitate the integration of these services in disciplines less familiar with GIS. The overarching objective was to foster effective collaboration between library GIS service providers and university faculty.

In a recent study, Mandel et al. (2023) conducted a comprehensive literature review in databases such as Library and Information Science Source (LISS) and Library, Information Science and Technology Abstracts (LISTA) with the aim of identifying the current trends in GIS and libraries. Similarly, the pioneering studies by Vardakosta and Kapidakis (2012) explored the field of geographic information management as it relates to academic libraries. Furthermore, the examination of information literacy for the utilization of geographic information has also been conducted (Branch, 2014). These studies yield results that provide new insights into the context of GIS and librarianship. However, there is a paucity of studies that address the analysis of scientific literature in the field of GIS on a global scale, with a particular focus on university libraries in databases such as Web of Science (WoS). This type of bibliometric approach allows for the identification of

previous trends or patterns that may influence or manifest themselves in scientific activity (Mandel et al., 2023). This is crucial as the evaluation of scientific production represents the materialization of academic and scientific activity at the level of the researcher, institution, or country. Its analysis across various fields of knowledge reveals a wealth of data and results that are vital for advancing and improving scientific research in development (Martínez et al., 2019).

Considering the above, the following research questions are posed:

- RQ_1: What is the current scenario of scientific production on geographic data and GIS in the university library environment?
- RQ_2: What gaps or research gaps are detected in the analysis that may represent an opportunity for future research?

The principal aim of this study is to analyze the scientific output of GIS and libraries in WoS, as well as to examine its evolution and identify the key areas of research. Given the growing influence of GIS in library management and its associated services, this study is presented as an opportunity to provide a visual representation of the field, identify gaps in the research landscape, and position GIS as a significant player in geographic data management.

2. METHODOLOGY

2.1. Data Collection and Definition of Search Strategy

A bibliometric approach was employed in the WoS database to examine research production and explore the

synergies between GIS and libraries. Bibliometrics is a field within documentation that employs quantitative analysis of bibliographic output, enabling the assessment of patterns, trends, and relationships within the scientific literature of an academic context. Ardanuy (2012) posits that bibliometrics utilizes a set of indicators that facilitate the quantitative expression of bibliographic characteristics of the studied document set and the existing relationships between these characteristics. Bibliometric indicators are numerical data derived from the bibliographic characteristics observed in published documents. They facilitate the analysis of various features of scientific activity pertaining to both the production and consumption of information. Production indicators are obtained by counting scientific publications, which are typically regarded as a measure of scientific activity (Martínez et al., 2019). To perform the analysis, a search strategy was initially developed and subsequently applied to the abstract, title, and keywords (TS field) in the WoS main collection, resulting in a total of 455 results. The strategy incorporates terms in both Spanish and English (Sistema Información Geográfico and geographic information systems). The search strategy is defined as follows:

> TS = ("Geographic Information System*" OR "GIS" OR "Sistema Información Geográfico" OR "SIG") AND TS = ("University Librar*" OR "Academic Librar*" OR "Library Service*" OR "Library Resource*" OR "Information Service*")

The data were downloaded on October 9, 2023, and included all documents (articles, reviews, conference papers, etc.) with no time limit.

2.2. Bibliometric Indicators

Following the download of the documents, the data were subjected to analysis, with the following indicators defined.

2.2.1. *Research Patterns*

- Annual scientific evolution: total number of documents per year.
- Scientific production by country: total number of articles per country in absolute values.
- Scientific production by universities or scientific institutions: most prolific institutions in the scientific production on the subject.

2.2.2. *Research Themes*

- Keyword co-occurrence analysis: This is a method of examining the thematic profile of a field by analyzing the frequency of simultaneous occurrence of a specific group of keywords in scientific articles. To this end, the VOSviewer tool was employed to identify the co-occurrence of article and author keywords. Each node's size indicates the number of publications associated with the keyword. Concurrently, the links represent the co-occurrences between two terms (the greater the number of instances of their joint occurrence, the higher the value), and the colors (clusters) indicate a higher affinity for topics. The terms have been normalized for visualization purposes, with a minimum frequency of five repetitions required to determine their relevance. The

normalization method employed was the Ling/Long modularity (Van Eck & Waltman, 2018).

3. RESULTS

The results are presented below, considering the indicators analyzed in the WoS database.

3.1. Annual Scientific Evolution

The search yielded a total of 95.82% scientific articles or conference papers (proceeding papers; Table 1), which constituted the majority of the search results.

Table 1. Distribution of the number of documents by type of document.

DOCUMENT TYPE	NUMBER OF DOCUMENTS OUT OF 455	PERCENTAGE (%)
Conference papers	226	49.67
Articles	210	46.15
Book review	7	1.53
Review article	6	1.31
Book chapter	3	0.65
Editorial material	3	0.65

Source: WoS and the authors.

The recovered documents span the period from 1993 to 2023, encompassing three decades of fluctuating trends in scientific production (Figure 1).

The number of publications per year exhibited a range between one and six articles between the years 1993 and 2001. However, from 2002 onwards, there was

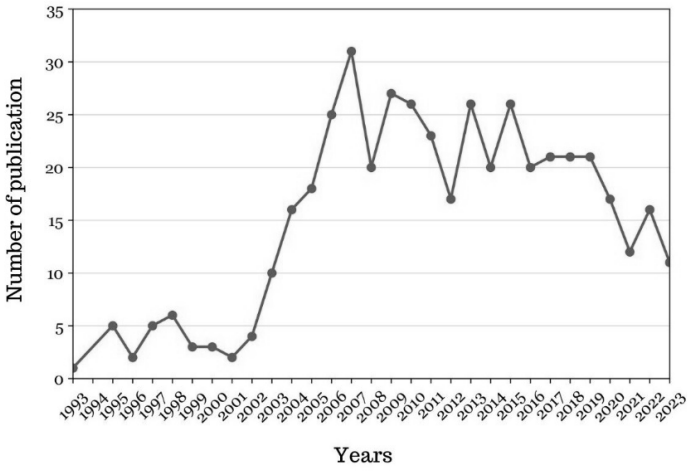

Figure 1. Evolution of the number of publications per year.
Source: WoS (2023).

a considerable increase in the number of publications, reaching 31 articles in 2007, which represented 87% of the initial value. From 2008 to 2023, there is a discernible downward trend in the number of publications, with 12 articles in 2021, representing the lowest annual figure over this period. It is important to note that the initial growth phase was relatively rapid, whereas the subsequent decline was both gradual and prolonged. The results indicate that the most notable scientific interest in GIS and academic libraries was observed between the years 2002 and 2003, with a gradual increase in subsequent years. The surge in scientific output between 2002 and 2007 coincides with the advent of GIS and the introduction of new technologies such as Nokia Maps (2001), Google Earth (2001), OpenStreet Maps (2004), Google Maps (2005), Microsoft Bing Maps (2005), and social networks. Furthermore, this period coincides with the advent of open-source versions

of GIS, including QGIS (Quantum GIS, 2001), PostGIS (2001), GeoServer (2003), and Mapnik (2005). In this context, GIS technologies, which had existed since 1960, could be used by non-specialized users to solve problems in other areas. However, this trend has not been increasing, with a 61% decrease between 2008 and 2023.

Table 2 presents a ranking of the 10 most frequently published journals in the field of GIS and university libraries. As can be observed, the journals with the highest number of publications are those in the areas of documentation and geography. The *Journal of Map & Geography Libraries* is a specialized journal that published the highest number of articles (33; 7.25%) on the subject between 2006 and 2022. The studies published in this journal address a range of topics related to GIS in libraries, including the availability of GIS in libraries, collaboration for the implementation of GIS projects, the evolution of GIS services in academic libraries, user analysis of library GIS services on mobile devices, collection management on digital maps, and case studies.

Table 2. Top 10 journals with the highest productivity between 2002 and 2023.

JOURNAL NAME	NUMBER OF JOURNALS OUT OF 455	PERCENTAGE (%)
Journal of Map & Geography Libraries	33	7.25
Journal of Academic Librarianship	13	2.86
Library Hi Tech	10	2.20
Library & Information Science Research	9	1.98

JOURNAL NAME	NUMBER OF JOURNALS OUT OF 455	PERCENTAGE (%)
ISPRS International Journal of Geo-Information	8	1.76
2009 17th International Conference on Geoinformatics, Vols 1 and 2	6	1.32
2010 18th International Conference on Geoinformatics	6	1.32
Library Trends	6	1.32
Geoinformatics 2007: Geospatial Information Technology and Applications, Pts 1 and 2	5	1.10
Information Technology and Libraries	5	1.10

Source: WoS and own elaboration.

It should be noted that other journals, which are not specifically focused on the field of documentation, have also published relevant material. These include the published proceedings of the annual IEEE International Geoscience and Remote Sensing Symposium (IGARSS) event from 2002 to 2005 and the Geoinformatics: The Geospatial Information Technology conference from 2006 and 2007 that published studies on new GIS models and trends, with the objective of increasing the scope of application of these technologies in other academic areas. The articles from these journals concentrate on the analysis and development of geographic information services for governments, utilizing online maps

on mobile devices with global positioning system (GPS) technology, geographic information services in the administration of public health information systems, and decision-making based on geographic information. Despite these subjects not falling within the remit of traditional library services, they have the potential to reinforce the provision of online information services, creating avenues for libraries to influence and address emerging information requirements.

3.2. Output by Country

It was determined that authors from 46 countries published on the subject of the study. Figure 2 illustrates a world distribution map by country according to the number of publications in absolute values.

Figure 2. Distribution of production by country. Source: WoS and own elaboration (2023).

China is among the most prolific countries, with 188 publications (41.31%), spanning the period from 2003 to

2023. The year 2007 saw the highest number of published articles (20). The United States follows with 121 publications (26.59%), with 2006 being the most productive year (10 publications). Subsequently, South Korea has contributed 17 publications (3.7%), Canada has contributed 15 publications (3.2%), Spain has contributed 12 publications (2.63%), the United Kingdom has contributed 11 publications (2.4%), and India, Italy, and Japan have contributed 10 publications each (2.1%). The remaining 46 countries have contributed between one and eight publications each. In the case of China, the studies address technical aspects of GIS, as well as information and data structure. An analysis of the keywords corresponding to these articles reveals a focus on map applications embedded in mobile devices, remote sensing, wireless technologies, data standards for GIS use, case studies, data reference models, data storage systems, and specialized geographic information services in areas such as marine, agriculture, fisheries, and urban planning.

The articles retrieved from the United States also encompass technical topics. Nevertheless, it is the country with the greatest number of publications, including academic libraries, that has the potential to make use of GIS. The articles retrieved from the United States include a variety of topics related to GIS, such as collection management, georeferencing services for libraries, mapping for the social sciences, the use of GIS in libraries during the coronavirus disease 2019 (COVID-19) pandemic for information and document exchange while libraries were closed, geolocated images of photo libraries, and geographic information management for librarians. It is noteworthy to mention the significant contributions of authors from this country in prominent journals such as the *Journal of Map &*

Geography Libraries (currently linked to the American Geographical Society Library), which has 24 publications.

3.3. Output per Institutions

Following an examination of the institutions in question, a set of 511 affiliations was identified that respond to universities and research centers. Figure 3 illustrates the 30 institutions that have published the most on GIS and university libraries. A total of 30 institutions (5.8%) have contributed at least four articles. The majority of these institutions are located in countries with a high level of output in this field, including China and the United States. Wuhan University in China is the leading institution, with 36 articles. These contributions are from various faculties, including the Wuhan University Faculty of Information Sciences, the Wuhan University Faculty of Sciences, the Wuhan University School of Resource and Environmental Sciences, the Wuhan University School of Remote Sensing and Information Engineering, and the Wuhan University State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing.

In the case of U.S. universities, the production of these institutions varies between four and seven articles from departments and research groups from different areas. However, research groups from the area of documentation participated. Within this panorama, the university systems of California and Ohio, together with North Carolina State University, are the ones that publish the most, with seven articles each, leading the publications with 14 articles that deal with topics where GIS and university libraries explicitly converge. The Universitat Jaume I (Spain), Harokopio University (Athens, Greece), and Liaoning Technical University (South Korea) have collectively published four

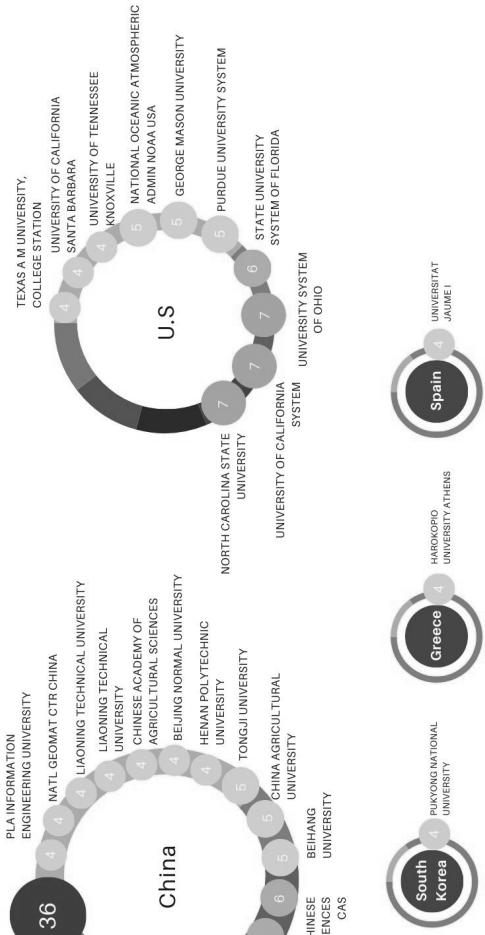

Figure 3. Top 30 institutions with the most publications. Source: WoS and own elaboration.

articles. These institutions have demonstrated a notable level of independence from China and the United States in their research output. The role of the Universitat Jaume I is particularly noteworthy, as three of its four articles are linked to researchers from the documentation departments.

3.4. Research Themes

Thematic analysis is employed to elucidate the central research axes present in the publications and their interrelationships. Figure 4 depicts the co-occurrence map. The nodes represent the key terms (keywords), while the links represent the connections between retrieved documents. Six clusters of topics are identified, each visualized with a unique color. The green cluster encompasses topics related to geography, library services, maps, and digital humanities. The light cluster includes web services, libraries, GIS, and information. The red zone in the center relates to spatial data and implementation. The nodes that make up the yellow cluster cover terms related to spatial data and implementation. The purple zone, although smaller, focuses on equity.

The most frequently occurring terms are "GIS" (180), "academic-libraries" (30), and "web-service" (22). The nodes with the strongest connections are GIS academic libraries (24), GIS and web service (13), and GIS and service (13). The largest cluster is that of GIS (red), which has 10 nodes and covers technical topics such as GPS, spatial analysis, and web, as well as the relevant nodes of academic libraries and information. The data demonstrate a notable discrepancy in frequency between the terms "GIS" and "academic libraries," which also exhibit the highest number of connections in the network. This suggests a growing thematic concentration on GIS in academic library

research. Clusters with fewer relationships and co-occurrences may influence research opportunities with GIS and other nodes within the network.

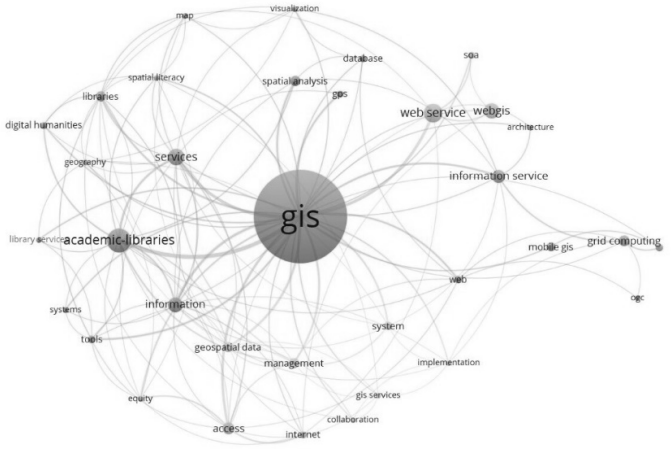

Figure 4. Keyword co-occurrence analysis. Source: WoS and own elaboration.

4. DISCUSSION

The results demonstrate a notable increase in studies related to GIS and academic libraries over the past two decades. This increase is most evident at the conclusion of the first decade of the 21st century, marking a period of sustained growth in research in this area and concomitant with the proliferation of GIS. However, as we approach the year 2023, there is a decrease in the production of new studies, which could indicate a stabilization or redirection of research efforts in this area. In response to RQ1, there is an irregular dynamic in academic interest and attention to the convergence between GIS and university libraries.

These findings align with those previously reported by Mandel et al. (2023), who conducted a comprehensive review of the scientific literature on GIS and libraries, utilizing the LISA and LISTA databases. The authors examined the titles and abstracts of the search results and collected articles that used GIS to measure and support library services, obtaining a total of 449 articles. Similarly, the data indicate a growth in publications in 2004 and a slight decrease from 2009 to 2019. Thus, it can be stated that the United States and China lead the scientific production in the field, generating a significant gap in comparison with European, Latin American, and Asian countries, which present fewer publications concerning these two main actors.

Wuhan University in China is the pre-eminent institution in the field. However, several of its publications originate from departments or faculties that are not entirely aligned with the aforementioned interests. These are associated with technical studies of systems and computing, as evidenced by the contributions of the Wuhan University Faculty of Information Sciences. Consequently, research opportunities are distinguished by a low degree of co-occurrence in relation to RQ2. Topics such as mobile GIS services and academic libraries are not identified with relationships within the network, which suggests the potential for influencing the development of geographic information services for academic libraries from mobile devices. Other terms such as "preservation," "collection management," "dissemination," "users," "pedagogy," and "open access" have a co-occurrence of less than five, indicating a limited connection with GIS and academic libraries. Despite the importance of these terms in advancing library services, their limited connection to GIS indicates specific areas that could benefit from further research and exploration.

The studies by Bishop and Mandel (2010) and Madel et al. (2023) reflect the introduction of two new categories: facility management and collection management. However, the authors do not mention "digital humanities," as illustrated in Figure 4. Digital humanities is a category directly related to GIS and their application in the social sciences and documentation. It is another area that conditions several lines of research that can enhance librarians' use of GIS technologies. Mandel et al. (2023), when compared to those of earlier studies conducted in 2010, indicate that the continued proliferation of technology and data analysis in libraries and among library researchers does not yet appear to result in substantial growth in the use of GIS. Despite the potential of GIS to facilitate research in a multitude of disciplines, the current evidence suggests that its uptake remains limited. To gain insight into this phenomenon, a comprehensive investigation is necessary, encompassing factors such as training, effective utilization of open-source software, and user literacy regarding GIS utilization.

This concept is corroborated by an analysis of reports from professional institutions, as evidenced by ACRL Research Planning and Review Committee (2022) and its annual top trends in academic libraries. In this publication, a section is dedicated to highlighting developments related to the utilization of library spaces during the course of the COVID-19 pandemic. While GIS are not expressly identified as pivotal tools for the development of library services or as a novel space for interaction with users, they are nevertheless referenced in a number of documents. However, an analysis of the retrieved documents reveals two publications that examine the use of GIS in the context of the pandemic. These are published in the *Journal of Map & Geography Libraries* and *Portal: Libraries and the Academy*. This

imbalance between interest and actual knowledge in the professional field on the application of these tools has a direct impact on the education and training of library staff. It is essential to emphasize the significance of WoS as a pivotal instrument in the present research, although its scope is inherently constrained. Undoubtedly, other bibliographic databases exist, which present a valuable avenue for future studies. A comparable analysis in LISA, LISTA, or Scopus would expand the research outcomes and potentially offer new insights, providing a foundation for further exploration and enhanced comprehension.

5. CONCLUSIONS

The findings of this study indicate that, despite the notable expansion of GIS research in academic libraries, the number of articles published over the past decade suggests that the topic is still evolving and has not yet attained the status of a fully established field of study. China and the United States are the leading countries in scientific production in the field of GIS and academic libraries. This position paper proposes that the predominant methodologies, techniques, and case studies in GIS are significantly influenced by the cultures and interests of the most prolific universities in scientific production. The direction of research in GIS and academic libraries appears to be shaped by the outstanding contributions of these nations, establishing sources of inspiration and a benchmark for the rest of the academic world.

The analysis of the topics addressed in the publications indicates a concentration of practical research and case studies, as opposed to theoretical research. Education, skills development, and training on GIS for librarians are rare topics, yet they are essential for promoting greater

scientific production, both theoretical and practical. This reality presents opportunities for research and innovation in academic library functions and may favor the future idea of consolidating the area. It is important to acknowledge the limitations of this study. First, we identified the articles explicitly related to each topic, that is, the "core" that includes the title, abstract, and keywords in the search terms. It is, therefore, possible that articles related to the topic that do not explicitly include the search terms may have been omitted. In future research, other search techniques (expansion methods through direct citations) will be included, in addition to defining a theoretical framework with a content-based analysis of the articles. Future studies on the topic could be complemented with qualitative research methods to discover motivations for GIS implementation in library contexts and their potential uses.

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