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Assessing publication trends in selected GIScience journals

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ABSTRACT

This study examines recent publishing trends in geographic information science (GIScience) journals. The study considers citable items (research articles, reviews) in 24 selected journals, and assesses them for the period between 2018 and 2023. The study begins by providing an overview of GIScience journal publishing trends, including growth in absolute numbers and the proportion in which they disseminate research as open access (OA). The geographic footprint of GIScience authors and international collaboration are also explored. Journals and their impact, reputation, and perceived quality are assessed using common journal metrics, including impact factor, 5-year impact factor, CiteScore, source normalized impact per paper (SNIP), SCImago Journal Rank (SJR), immediacy index, article influence score and normalized Eigenfactor. A composite index consisting of all these metrics from 2022 is established. The paper finds that GIScience is increasingly disseminated as OA. There is evidence that the Global South is underrepresented in GIScience, which necessitates greater inclusion and support in these regions. Finally, the assessment of journal metrics helps researchers identify prominent GIScience journals for disseminating their work effectively. This paper contributes to the knowledge and understanding of recent publishing trends in GIScience, offering valuable insights to researchers, practitioners and journal editors.

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1. Introduction

The term geographic information science (GIScience) was coined to describe a framework and academic discipline rooted in theory and science (Goodchild 1992). It was born as a response to critiques of geographic information systems (GIS), that is practical and technical, hence is not considered a scientific discipline (Goodchild 2010, Egenhofer *et al.* 2016). There is no doubt that over the last three decades, GIScience went beyond the technical nature of GIS and has established itself as a legitimate

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scientific discipline. Naturally, as a result of this, GIScience specific conferences and journals emerged that facilitate the exchange of ideas and disseminate research, as well as university departments and professional organizations formed to advance the discipline.

At the same time, important concepts, such as open science and open access (OA) publishing are revolutionizing science and how research is disseminated (Fecher and Friesike 2014). These emphasize accessibility and transparency in scientific knowledge. These movements ensure that research as a whole (including data, methods and outputs) are accessible to all of society, fostering an inclusive academic community. Journal-based metrics are commonly used to measure the quality of research items and to assess the contributions of individual scientists, despite the fact that the scientific context of research outputs would be a more important evaluation criteria (The American Society for Cell Biology 2012). Still, journal metrics attempt to offer quantitative measures for evaluating research impact and institutional prestige, and therefore they play a significant role in promotions, funding and shaping of publication strategies, such as aiming to publish in journals with high impact factor (IF) (McKiernan *et al.* 2019).

Science, however, is not homogeneous and every discipline has their own unique identity. For this reason, it is difficult to uniformly assess how new concepts are being adapted across disciplines. This necessitates regular, field-specific assessments. This research aims to contribute to this topic. It takes stock of current GIScience publishing trends and it extends previous studies by including emerging journals in the analysis. In general, this paper aims to provide practical insights for the GIScience community to help evaluate itself concerning topics, such as OA publishing and international collaboration. It does so by investigating the following questions:

- How have publication volumes in GIScience journals changed recently?
- What portion of GIScience publications are disseminated as OA?
- What is the geographic footprint of authors that publish in GIScience journals?
- What is the international collaboration network of GIScience publications like?
- How do different GIScience journals perform across a range of metrics?

1.1. Related work

1.1.1. The identity of GIScience

A series of studies have contributed to understanding trends and patterns in GIScience publications. A challenge is that the discipline itself is not homogeneous and is difficult to define. Goodchild (2010) and Egenhofer *et al.* (2016) provide detailed historical accounts of the beginning of GIScience (late 1980s to early 1990s), including early definitions and debates. The discussion to define GIScience and establish its identity has continued over the decades with many authors contributing to the discourse (Wright *et al.* 1997, Reitsma 2013, Blaschke and Merschdorf 2014, Guan *et al.* 2019). More recently, a similar conversation emerged about geographic data science and how it integrates with data science, geography and GIScience (Scheider *et al.* 2020, Singleton and Arribas-Bel 2021).

After several decades of progress, GIScience is considered a discipline on its own merit, but deciding what constitutes a GIScience journal is still difficult due to the inherent multidisciplinary nature and fuzzy boundaries of the field. It encompasses a wide array of elements that range from surveying (engineering) to cognitive sciences, which are themselves interdisciplinary (Goodchild 1995). From the published literature, Blaschke and Merschdorf (2014) identified other disciplines that contribute to GIScience. The most important ones were computer science, geography, information sciences, environmental sciences and ecology, engineering, geology and remote sensing. While this extended list gives a more nuanced picture about the identify of GIScience, it is by far not complete. Urban studies and science, for example, were found to contribute to only about 1–2% of total GIScience publications, whereas by today, urban studies (also called urban data science) are clearly intertwined with GIScience (Biljecki and Ito 2021). Other challenges in identifying contributing disciplines are the fact that many researchers who identify as GIScientists publish in different outlets (Kuhn and Brox 2011), and that they might be embedded in 'outside' departments and teach and conduct research under the umbrella of other fields such as computer science, planning or sociology (Westerholt 2023).

Identifying GIScience research themes is a topic of interest in bibliometric and scientometric studies. Various techniques have been applied on GIScience-related bibliometric datasets, such as latent semantic analysis of 985 research articles between 1997 and 2007 published in six journals (Parr and Lu 2010), topic modeling on over 16,000 articles between 1990 and 2017 from 17 journals (Huang 2022) and community detection in citation networks based on 9400 publications between 1991 and 2020 in 10 journals and two conferences (Wu *et al.* 2023). Yan *et al.* (2020) applied a similar approach to volunteered geographic information (VGI) research, a sub-field of GIScience. While identifying specific research themes are not the primary focus of this paper, the studies mentioned here arguably provide another dimension in terms of subjects and topics covered in GIScience.

1.1.2. Prior publications trends in GIScience

These complexities mentioned above render determining what constitutes a GIScience journal a challenging task. A comprehensive discussion of the problem of identifying GIScience journals is given by Biljecki (2016). Furthermore, this same study analyzed over 12,000 papers published in 20 GIScience journals from 2000 to 2014. Key findings include a steady growth in the number of articles and concentration of global GIScience output by a small percentage of countries. The paper also analyzed citations, and found a median of 12 citations for a 15-year-old paper, and a significant increase in international collaborations in GIScience over the study period. Other studies confirmed that the number of GIScience publications continued to rapidly grow in the following years (Huang 2022, Wu *et al.* 2023).

In an editorial, Jiang (2011) argues that following other data-intensive disciplines GIScience should embrace the concept of openly sharing research data and source code, as well as OA publication. Although not mentioned explicitly by Jiang, this is in-line with the open science movement, first described by Chubin (1985). Open science aims to make scientific research, including data and software accessible for everyone.

Reproducibility, a related concept also part of the open science framework requires a paradigm shift, and will require a lot of effort from the GIScience community to achieve. However, these concepts are gaining traction in recent years. Singleton *et al.* (2016) describe a framework for open GIScience, while Shannon and Walker (2018) conduct case studies to make GIScience research available and explorable for a wider audience. A reproducible research initiative has also been implemented as part of the AGILE (Association of Geographic Information Laboratories in Europe) conference series in Europe (Nüst *et al.* 2018), and important issues with sharing data, such as provenance and location privacy are also being considered (Keßler and McKenzie 2018, Tullis and Kar 2021).

It was shown that the geographic distribution of GIScience research is concentrated in certain countries, notably the United States, Mainland China, Germany, United Kingdom and Canada. This reflects geographical biases and regional interests (Parr and Lu 2010, Wu *et al.* 2023). The list of top countries was found more or less the same when looking at a sub-field of GIScience focusing on VGI (Yan *et al.* 2020) and OpenStreetMap research (Grinberger *et al.* 2022).

Biljecki (2016) analyzed how IF correspond to mean citations in a journal. This study also showed a weak connection between altmetrics (alternative metrics) and IF. In the broader context of science, it is generally accepted that journal metrics are often misused (Pendlebury 2009), and even abused in cases (Hicks *et al.* 2015). While IF and other metrics are still commonly used in evaluations, such as for tenure and promotion (McKiernan *et al.* 2019), many stakeholders are openly questioning this practice or even moving away from using flawed metrics. For example, the San Francisco Declaration on Research Assessment (DORA) published by The American Society for Cell Biology (2012) has been increasingly adopted by institutions from all around the world to improve how scholarly output is evaluated.

1.2. Significance of this study

The contributions of this article are manyfold. In a general sense, it provides an assessment of current trends in journal publishing in GIScience. This research also provides a first overview of OA trends, which has not been widely discussed in the GIScience literature yet. The paper analyzes publication volume, OA publishing, geographic footprint of GIScience articles and international collaboration. This allows comparison with other disciplines to see how our publishing practices fit in the larger realm of science. The comprehensive assessment of journal metrics provides an overview of the diverse options available to GIScientists. This paper extends previous studies by including emerging journals in the analysis. The journal assessment can serve as a useful resource for academics in all career stages.

2. Materials and methods

2.1. Selecting GIScience journals

Even though selecting GIScience journals is ambiguous (see Section 1.1), several previous studies came up with lists of GIScience journals. Based on answers from 40 international experts, Caron *et al.* (2008) ranked several GIScience journals. This eventually resulted in a multi-year discussion as part of the AGILE conference series aimed to develop a standardized way to rank GIScience journals (Kuhn and Brox 2011, Kemp *et al.* 2012, 2013). Later, Egenhofer *et al.* (2016) compiled a list of 16 journals based on panel discussion of journal editors interested in soliciting GIScience articles. A more extensive list was established by Biljecki (2016) as part of a comprehensive scientometric analysis of published GIScience articles. This list of journals serves as the foundation of subsequently related studies (Huang 2022), including this article. However, GIScience is still rapidly changing, therefore adjusting this list is necessary due to the emergence of new journals. In addition to journals analyzed by Biljecki (2016) and Huang (2022), this paper considers five emerging journals that were not included in previous studies. These are *Annals of GIS* (AGIS), *Applied Geography* (APG), *Geo-spatial Information Science* (GSIS), *Journal of Geovisualization and Spatial Analysis* (JGSA) and *ACM Transactions on Spatial Algorithms and Systems* (TSAS).

Table 1 lists the final set of 24 selected GIScience journals included in this study. It has to be pointed out that this list is not exhaustive, and is inherently subjective. However, since GIScience is not included in scientometric databases as a separate discipline, an authoritative and widely accepted list of GIScience journals does not exist. Table 1 also shows additional information about these journals, more specifically, their publishers, peer-review policy and the OA model. A journal employs a hybrid OA

Table 1. List of GIScience journals included in the study.

ID	Journal	Publisher	Peer review	Preprint	OA	APC (US$)
AAG	*Annals of the American Association of Geographers*	T&F	D	No	Hybrid	3300
AGIS	*Annals of GIS*	T&F	D	No	Full	1680
APG	*Applied Geography*	Elsevier	D	No	Hybrid	2900
C&G	*Computers & Geosciences*	Elsevier	S	Yes	Hybrid	3630
CaGIS	*Cartography and Geographic Information Science*	T&F	D	No	Hybrid	3500
CEUS	*Computers, Environment and Urban Systems*	Elsevier	D	No	Hybrid	3740
EPB[a]	*Environment and Planning B*	Sage	D	No	Hybrid	3250
G&RS	*GIScience and Remote Sensing*	T&F	S	Yes	Full	2630
GEAN	*Geographical Analysis*	Wiley	D	No	Hybrid	3760
GEIN	*Geoinformatica*	Springer	S	Yes	Hybrid	2590
GSIS	*Geo-spatial Information Science*	T&F	D	No	Full	2070
IJDE	*International Journal of Digital Earth*	T&F	D	No	Full[b]	2630
IJGI	*ISPRS International Journal of Geo-information*	MDPI	S	Yes	Full	1890
IJGIS	*International Journal of Geographical Information Science*	T&F	D	No	Hybrid	3650
JAG	*International Journal of Applied Earth Observation and Geoinformation*	Elsevier	S	Yes	Full	2400
JGS	*Journal of Geographical Systems*	Springer	D	No	Hybrid	3090
JGSA	*Journal of Geovisualization and Spatial Analysis*	Springer	D	No	Hybrid	2990
JOSIS	*Journal of Spatial Information Science*	–	S	Yes	Full	0
JSS	*Journal of Spatial Science*	T&F	D	No	Hybrid	3175
P&RS	*ISPRS Journal of Photogrammetry and Remote Sensing*	Elsevier	S	Yes	Hybrid	3310
PE&RS	*Photogrammetric Engineering and Remote Sensing*	ASPRS	D	No	Hybrid	1500[c]
SCC	*Spatial Cognition and Computation*	T&F	S	Yes	Hybrid	3175
TGIS	*Transactions in GIS*	Wiley	S	Yes	Hybrid	3450
TSAS	*ACM Transactions on Spatial Algorithms and Systems*	ACM	S	Yes	Hybrid	1800

T&F: Taylor & Francis; MDPI: Multidisciplinary Digital Publishing Institute; ACM: Association for Computing Machinery; D: double-blind peer review; S: single-blind peer review.
[a]Changed from Environment & Planning B: Design and Planning to Environment & Planning B: Urban Analytics and City Science in 2019.
[b]IJDE transitioned to full open access from Vol. 15 (2022).
[c]Waived for primary authors from subscribing institutions and individual members of ASPRS.

model if they publish both traditional (subscription-based) and OA articles. Full OA journals only publish OA. For OA publications, the table also lists the article processing charge (APC) that is paid by authors or their institutions to make an article freely accessible. The preprint column implies whether at the time of submission to a journal, authors are allowed to deposit a copy in preprint servers. The table was manually compiled from journal homepages. When a policy was not explicitly stated on the website, clarification from the editorial staff or publisher was sought via email.

2.2. Journal metrics

Several metrics can be used to provide insights into the academic impact, influence and reach of journals. This study considers the following, commonly used and easily accessible metrics.

- *Impact factor*: Measures the average number of citations received in a particular year by papers published in the journal during the two preceding years.
- *CiteScore*: Calculates the average citations received per document published in the journal. It considers a four-year publication window, offering a broader scope than the IF.
- *Source normalized impact per paper (SNIP)*: Measures the contextual citation impact by weighting citations based on the total number of citations in a subject field. It provides a more field-specific understanding of citation impact.
- *SCImago Journal Rank (SJR)*: Measures the scientific influence of the average article in a journal. It considers both the number of citations received by a journal and the importance of the journals where such citations come from.
- *5-Year impact factor (IF5yr)*: Similar to the traditional IF, this metric averages the number of citations received in a particular year by papers published in the journal in the previous five years.
- *Immediacy Index (Imm)*: Measures the average number of citations received in a given year by articles published in the same year. It helps gauge how quickly articles in a journal are cited upon publication.
- *Article Influence Score (Influ)*: This metric reflects the average influence of a journal's articles over the first five years after publication. It is calculated by dividing the Eigenfactor Score by the number of articles in the journal, normalized as a fraction of all articles in all publications.
- *Normalized Eigenfactor (Eigen)*: The calculation is based on the number of times articles from the journal published in the past five years have been cited in the current year. This metric adjusts for differences in citation practices across disciplines, making it possible to compare journals from different fields.

While the *H*-index, defined as the number of publications in a journal that received at least the same number of citations is also commonly used, this metric is heavily influenced by the age and size of a journal, therefore, it was not used in this study. Each of the metrics offers a unique lens through which the influence and academic standing of GIScience journals can be assessed. IF, CiteScore, SNIP and SJR were analyzed between 2018 and 2022 to gain a comprehensive understanding of not only the journals' impact on GIScience but their evolution. In addition, IF5yr, Imm, Influ and Eigen were used to provide a current ranking of GIScience journals.

2.3. Data collection and processing

Metrics described in the previous section for each journal and year were manually collected from the following online services on 1 December 2023.

- Journal Citation Reports (https://jcr.clarivate.com/): IF, IF5yr, Eigen, Imm, Influ;
- Scopus Sources (https://www.scopus.com/sources.uri): CiteScore;
- SCImago (https://www.scimagojr.com/journalrank.php): SJR;
- CWTS Journal Indicators (https://www.journalindicators.com/): SNIP.

A detailed list of published items between 2018 and 2023 was downloaded through the Scopus API for each journal and saved in CSV files on 3 March 2024. Several metadata fields were retained, such as a unique ID, title, DOI (digital object identifier), article type, OA status and publication date. Author affiliations in this dataset were found to be incomplete, therefore, in a separate step, author affiliations were extracted separately for each article through the same API. CSV files then were processed using standard Python packages. The dataset and processing scripts are available as Supplementary Material.

First, publication volumes were aggregated by journal and year. Some published items such as editorials, errata, etc. were excluded and only research and review articles were counted. These items are peer-reviewed and traditionally considered as citable. To assess who contributes to GIScience research, the affiliation (i.e. institution), jurisdiction and city were extracted. The paper considers special administrative regions (e.g. Hong Kong, Macau) and other non-sovereign entities, therefore, adapting the term jurisdiction instead of country is more inclusive. Different approaches to normalizing multi-author and cross-border contributions exist. Some previous studies used fractional counting (Biljecki 2016, Grinberger *et al.* 2022), i.e. assigning $1/n$ score for each contributing author (where n is the number of authors), so that the total score for each article is 1. Another approach is considering the order of authors in the scoring (Gauffriau *et al.* 2008), while others develop more sophisticated methods and weight different contributions (e.g. writing, data collection, interpretation of results, etc.) to construct an overall contribution score for authors (Masud *et al.* 2020). In this study, I count every unique affiliation and jurisdiction associated with an article with full score. This approach puts more emphasis on the actual footprint of GIScience, where any party (institution, jurisdiction) involved in GIScience research articles would appear with the same weight.

To measure international collaboration, unique jurisdiction-pairs were also established for each publication. For example, considering a four-author paper where two authors are affiliated with the United States, and the remaining authors are from a Japanese and German institution, the retained country pairs are *United States – Japan*, *United States – Germany* and *Japan – Germany*. This results in a network where nodes are jurisdictions and links between them represent the number of papers these two jurisdictions collaborated in.

2.4. Analysis methods

To quantify the growth of journals, the compound annual growth rate (CAGR) was calculated, which shows the average yearly growth between a start and end year. It can be formulated as follows:

$$\text{CAGR}(t_0, t_n) = \left(\frac{V(t_n)}{V(t_0)}\right)^{\frac{1}{t_n - t_0}} - 1 \tag{1}$$

where CAGR is the compound annual growth rate, $V(t_0)$ is the number of articles published at the beginning of the study period (2018), $V(t_n)$ is the number of articles published at the end of the study period (2023) and $t_n - t_0$ is the time period in years.

Simple linear regressions were used to measure the association between the economic performance of a jurisdiction and research output. While they are useful for understanding relationships between two variables, more complex models are required when dealing with less straightforward relationships. Linear mixed-effects models are a type of regression model that accommodates both fixed and random effects. They are particularly useful in analyzing data where observations are not independent from each other (McLean *et al.* 1991). In this study, the linear mixed-effects model was employed to analyze the year-on-year variation in the percentage of OA articles across different journals. The general form of a linear mixed-effects model can be represented as:

$$Y = X\beta + Z\gamma + \varepsilon \tag{2}$$

where Y is the response variable (in our case, the percentage of OA articles), X and Z are matrices of covariates for fixed effects (β) and random effects (γ), respectively. The term ε represents the residual errors.

In this model, the fixed effect is the year, capturing the overall trend in OA publishing. The random effect is the journal, accounting for the variability among different journals. By including journals as a random effect, I control for the inherent differences between journals, allowing for a more accurate assessment of the overall trend in OA publishing. A linear mixed-effects model accounts for the inter-journal variability and characterizes the general trend in OA publishing.

When evaluating performance of jurisdictions, the number of articles was normalized. Population estimates were used to control for size, and the gross domestic product (GDP) and income group classifications (i.e. high (OECD and non-OECD), upper middle, lower middle and low income) were used as proxies to economic status. Jurisdictions and their income group are listed in the Supplementary Material. The source of these data is the World Bank through the public domain Natural Earth dataset (accessed in R by *rnaturalearth*; Massicotte and South 2023). To explore the relationship between a jurisdiction's economic status and its engagement in GIScience publishing, I applied the non-parametric Kruskal–Wallis rank-sum test to explain the distribution of article involvements per 1 million population across different economic groups within the dataset. This approach highlights variations in GIScience publishing relative to economic status within the defined set of jurisdictions. Following the Kruskal–Wallis test, Dunn's post hoc test was applied to identify specific group differences. Dunn's test is used for multiple comparisons of groups after a Kruskal–Wallis test. This method allows for a more detailed understanding of which specific economic groups differ in their article involvement relative to their population.

Journals were ranked from 1st to 24th for all metrics and years. In case of a tie, the lower rank was assigned to both journals. In case a metric was missing, which could happen when a journal did not meet the criteria for a metric, the rank 24 was assigned to signify the fact that the particular journal performed worse than other journals that had a score. This was the case for AGIS, GSIS, JGSA, JOSIS and TSAS for IF (see also Section 3.3). The correlation between journal metrics was assessed using Spearman's rank correlation, which is suitable for ordinal data. All metrics for 2022 (see Section 2.2) were averaged to create a composite metric. This meta-ranking is commonly used to establish a journal ranking system across metrics (Bradshaw and Brook 2016, Rodriguez *et al.* 2020).

Agglomerative hierarchical clustering was used to determine the presence of journal clusters, i.e. groups of journals with similar performance across metrics. All eight metrics used in the composite ranking were used to create clusters. The distance between clusters is computed as the average Euclidean distance between all pairs of points in the clusters. The validity of identified clusters was assessed via calculating approximately unbiased *p* values (AU) using multiscale bootstrap resampling (10,000 replications) (Shimodaira 2004, Suzuki and Shimodaira 2006, Terada and Shimodaira 2017). Clusters with high AU values are more likely to represent meaningful or natural groupings, as opposed to those formed by chance.

2.4.1. Note on the dataset and statistics

In the context of this research, it is crucial to clarify the nature of the dataset. The analysis treats the set of GIScience journals included in the study as the whole population, while recognizing the subjectivity of this selection (see Section 2.1). This approach means that I am not dealing with a sample from which I infer characteristics about a larger population; rather, I am examining the population itself. The statistics used in this paper serve to describe and analyze the characteristics and dynamics within these GIScience journals. In this context, the role of *p* values is descriptive rather than inferential. They do not imply statistical significance in the traditional sense of inferring about a larger population but are used here to describe the strength and patterns of relationships within the dataset. This distinction is important for interpreting the results accurately.

3. Results

3.1. Dissemination of GIScience research

3.1.1. Volume of publications

A total of 16,503 articles have been published between 2018 and 2023 in the selected GIScience journals. Figure 1(a) reveals an upward pattern with the yearly number of articles increasing from 2164 to 3174 between 2018 and 2023. However, this growth

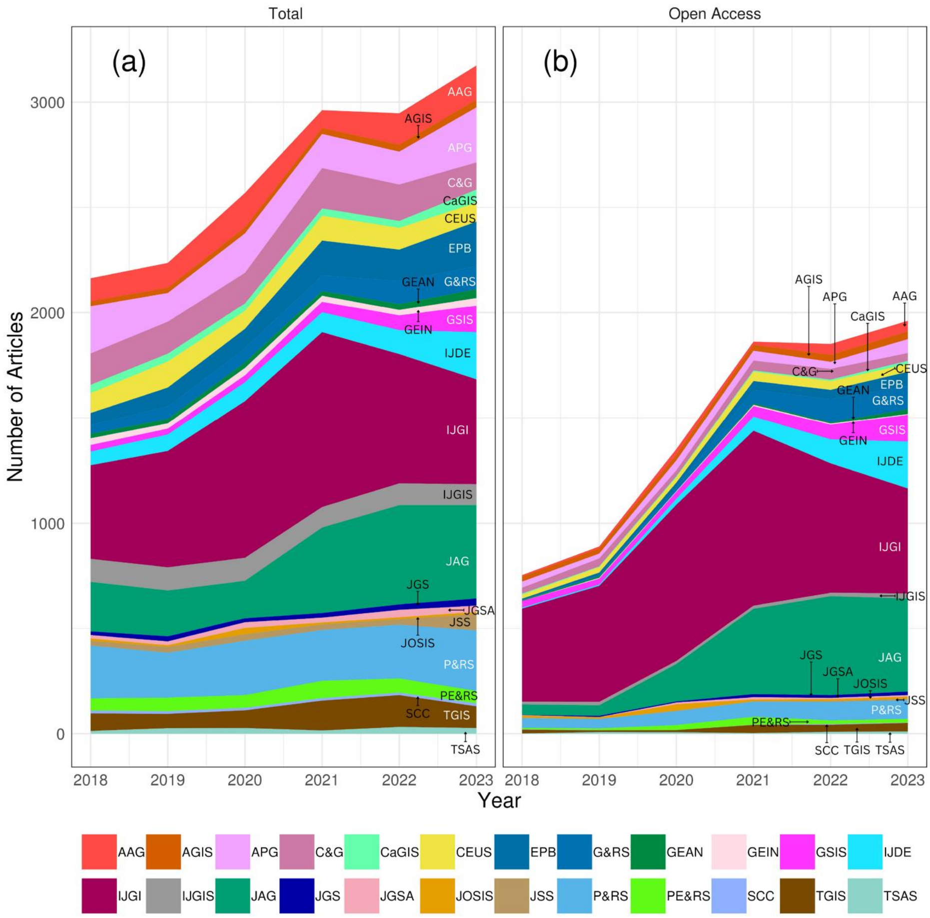

Figure 1. Number of articles published in selected GIScience journals (a); and OA articles published over time (b).

can be attributed to only a handful journals that increased their publication volumes at a fast rate, while other journals remained consistent. In fact, the top 25% (six out of 24) fastest growing journals based on their CAGR between 2018 and 2023 are responsible for 54% of the growth, indicating a skewed distribution. These six journals (EPB, G&RS, GSIS, IJDE, JSS and TSAS) have a mean CAGR of 26% in contrast to 5% of the remaining 18 journals. Thirteen journals published less articles at least once than in a previous year, and four journals have negative CAGR between 2023 and 2018. Six journals (APG, CaGIS, GEIN, IJGIS, JOSIS and SCC) decreased their publication outputs in at least 3 years in the study period. The change in absolute published articles and CAGR for individual journals is shown in Table S1 in the Supplementary Material.

Figure 1(b) shows a similar overall trend for OA articles with outputs increasing from 754 to 1961. The proportion of OA articles among all journals rose from 35% in 2018 to 63% by 2021 and remained at 62% in 2023 (grey line in Figure 2). Some of the journals included in the study employ a full OA model (see Table 1). For hybrid journals, the percentage of OA articles over the study period is depicted in Figure 2.

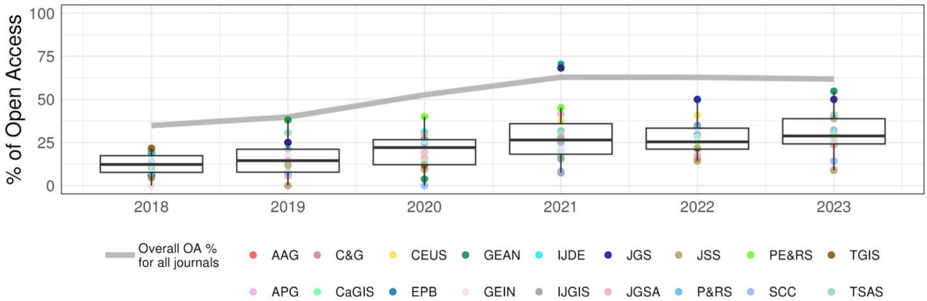

Figure 2. Percentage of OA articles in hybrid and traditional GIScience journals between 2018 and 2023 as well as the overall OA % for all journals (grey line). IJDE is excluded in 2022 and 2023 following its transition to full OA.

The plot reveals that an increasing portion of all articles are published OA. This trend can be modeled using a linear mixed-effects model to describe the year-on-year variation in the percentage of OA articles. In this model, journals are treated as a random effect to account for inter-journal variability. The analysis indicates an average 3.9% yearly increase in the proportion of OA articles from 2018 to 2023 ($est. = 3.9;\ std.error = 0.6;\ df = 88;\ t = 9.0;\ p < 0.001$), demonstrating a consistent upward trend in OA publishing across the journals. This suggests a substantial shift in publishing practices toward OA, which aligns with the visual trend depicted in Figure 2.

3.1.2. Preprints and APCs

A related concept to OA publishing is openly sharing preprint versions of submitted articles, which is common in some other disciplines, e.g. physics, computer science and computational biology. Eleven journals listed in Table 1 allow sharing preprints. These journals also run a single-blind peer-review process. On the other hand, the remaining 13 journals operate double-blind peer-review. Posting a preprint violates double-blind peer-review since anonymity cannot be guaranteed, hence, posting a preprint version of articles submitted to these journals is not allowed. Although a systematic analysis of GIScience preprints cannot be conducted, a quick search on arXiv, a leading preprint server, for the terms 'GIScience' and 'geographic information science' yields over 200 results. This suggests that preprints are shared by the GIScience community. Since there is no GIScience category in arXiv, these articles represent a subset of GIScience articles that are most relevant for computer science as a separate discipline. There are also multiple other preprint hosting services (e.g. EarthArXiv, ResearchGate and Preprints.org). For these reasons, the number of GIScience preprints is likely much larger than this.

APCs are charged by journals to authors or their institutions to make an article OA. Most GIScience journals charge APCs (see Table 1). Two exceptions are JOSIS, that does not charge APC, and PE&RS that waives APCs for subscribing institutions. Unlike other journals included in this study, these are not managed by traditional publishers. JOSIS is entirely volunteer-run as a service to the GIScience community, while PE&RS is operated by the American Society for Photogrammetry and Remote Sensing (ASPRS).

When excluding JOSIS, APCs range from \$1680 (AGIS) and \$3760 (GEAN) with an average of \$2934 and median of \$3175. This can be a significant barrier to disseminating research, especially for early-career researchers without established funding, and for authors affiliated with institutions in less developed regions (Williams *et al.* 2023). It has to be noted that some institutions and publishers offer financial assistance (e.g. waived or reduced APCs) in certain circumstances. However, this is usually implemented through agreements between institutions, organizations and publishers rather than individual journals, therefore, it is not discussed in this study. Moreover, research suggests that fee waivers can have unintended side-effects, such as artificially distorted co-author networks (Edem *et al.* 2021, Borrego 2023). Edem *et al.* (2021) showed that low-income countries form co-author networks differently from other economic groups, as they are more likely to include co-authors from wealthier countries when publishing OA articles in MDPI journals. While this may help researchers who lack resources participate in scholarly publishing, the practice has also been described as the 'free rider' problem that puts stress on larger, research-oriented institutions to cover publication fees for their peers (Courant and Jones 2015, Borrego 2023).

3.2. Distribution and collaboration

3.2.1. Geographic distribution

Authors with affiliations in 144 jurisdiction were found to have contributed to at least one GIScience article within 2018–2023. The distribution is shown in Figure 3(a) geographically, and as a histogram in Figure 3(b). The distribution of countries did not change significantly since Biljecki (2016)'s study. The top 10 jurisdictions that are involved in GIScience research are the same that was found to dominate GIScience in 2016. At least one author from these top jurisdictions is involved in 73% of all GIScience research outputs. The most notable change is that Mainland China surpassed the United States, and authors with these affiliations are involved in over twice as many articles, which is a continuation of the rising number of outputs by Mainland China. On the other end of the spectrum, 65 jurisdictions did not take part of the global GIScience research between 2018 and 2023.

Table 2 shows the article involvement by city, which is similarly dominated by Mainland China. Although Beijing and Wuhan were the top two cities in Biljecki (2016)'s study, a major change is that the first cities outside Mainland China and Hong Kong are London, United Kingdom and Enschede, The Netherlands at the 11th and 12th place, respectively (compared to 3rd and 4th in 2016). The most highly ranked cities from the remaining continents are Melbourne, Australia from Oceania (19th), Washington, D.C., USA from North America (28th), Santiago de Chile from South America (95th) and Pretoria, South Africa from Africa (96th). The distribution of cities in the top two jurisdictions appears to be different. 213 unique cities in Mainland China were recorded in the dataset in contrast to 488 cities in the USA. Figure 4 plots the locations in these regions and confirms that GIScience research appear to be more centralized in Mainland China compared to the USA where cities are more evenly distributed.

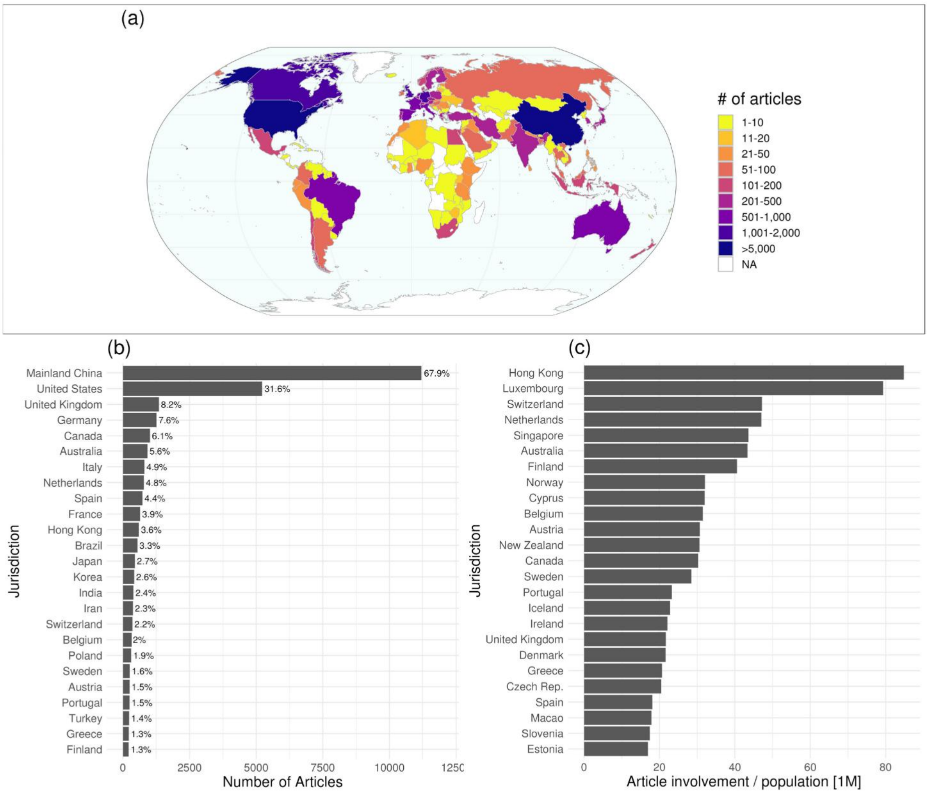

Figure 3. Map of jurisdictions by their involvement in GIScience articles (a); histogram of article involvement by jurisdiction (b); histogram of article involvement normalized by population (in million people) (c).

Table 2. Top 30 cities ranked by GIScience article involvement.

Rank	Jurisdiction, city	# of articles	% of total	Rank	Jurisdiction, city	# of articles	% of total
1	China, Beijing	3611	22.5	16	China, Qingdao	236	1.5
2	China, Wuhan	1885	11.7	17	Australia, Sydney	216	1.4
3	China, Nanjing	1053	6.6	18	Singapore, Singapore City	203	1.3
4	China, Hong Kong	599	3.7	19	Australia, Melbourne	200	1.3
5	China, Guangzhou	583	3.6	20	South Korea, Seoul	200	1.3
6	China, Shanghai	530	3.3	21	Japan, Tokyo	198	1.2
7	China, Chengdu	459	2.9	22	Switzerland, Zurich	195	1.2
8	China, Hangzhou	322	2.0	23	China, Fuzhou	191	1.2
9	China, Shenzhen	321	2.0	24	Italy, Rome	180	1.1
10	China, Xi'an	299	1.9	25	Germany, Munich	173	1.1
11	United Kingdom, London	282	1.8	26	China, Lanzhou	162	1.0
12	Netherlands, Enschede	272	1.7	27	Canada, Toronto	161	1.0
13	China, Changsha	269	1.7	28	United States, Washington, D.C.	157	1.0
14	China, Zhengzhou	253	1.6	29	Netherlands, Delft	153	0.95
15	Iran, Tehran	248	1.5	30	United States, Tempe	153	0.95

3.2.2. Article output in relation to economic performance

The absolute numbers of involvement are influenced by the size of jurisdictions and therefore does not accurately reflect how efficient these jurisdictions are. Figure 3(c)

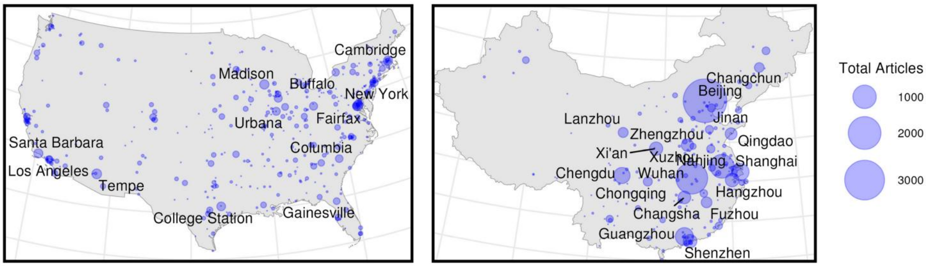

Figure 4. Map of cities with GIScience contributions in the continental USA (left) and in Mainland China (right).

normalizes article involvement by the population estimate of the jurisdiction. From the top 10 list by absolute involvement (Figure 3(b)), only Australia and the Netherlands appear in the top 10 jurisdictions by normalized article involvement. Interestingly, the top economic performers (G7 countries) are not the most efficient ones. While six out of seven G7 states are part of the top jurisdictions based on total numbers (Japan is missing), only Canada comes close to making top 10 on the normalized list (11th place). However, this does not mean that economic activity does not play a role in GIScience publishing. A Kruskal–Wallis rank-sum test conducted on the article involvement per shows that the difference between the medians of income groups is not caused by random chance ($df = 4;\ \chi^2 = 94.86;\ p = 0$). Dunn's post hoc tests further clarify these differences. The two groups of high income jurisdictions (OECD and non-OECD members) do not show a difference in publishing activity. When comparing high-income economies (both OECD and non-OECD) with other income groups, there is a noticeable decrease in publishing activity as income levels decrease. This suggests that economic resources play a crucial role here.

Figure 5(a) shows the relationship between economic activity and involvement in GIScience articles. A simple linear regression model, fitted on the per capita GDP (expressed in thousand US$) and the number of articles involved per 1M residents demonstrates that higher GDP per capita is associated with an increase in the number of articles, with a coefficient estimate of 0.61, highlighting the positive correlation between economic activity and scientific output in GIScience ($R^2 = 0.52$).

There is also a strong linear relationship between the number of OA articles in a jurisdiction and the number of total articles ($R^2 = 0.97;\ F(1,127) = 3872$). For this analysis, the USA and Mainland China were removed as outliers. Figure 5(b) shows this relationship ($\beta = 0.58;\ std.error = 0.01$). No relationship was found between the economy of a jurisdiction, either measured by GDP per capita, or income groups, and the percentage of OA articles. This suggests that all jurisdictions disseminate their GIScience research as OA with the same rate.

3.2.3. International collaboration

Roughly one third of all articles (5294 out of 16,503) in the study period were a result of international collaboration. The share of international articles seems to have been stabilized around 30–35% with yearly values ranging between 30.3% in 2023 and 35.4% in 2018.

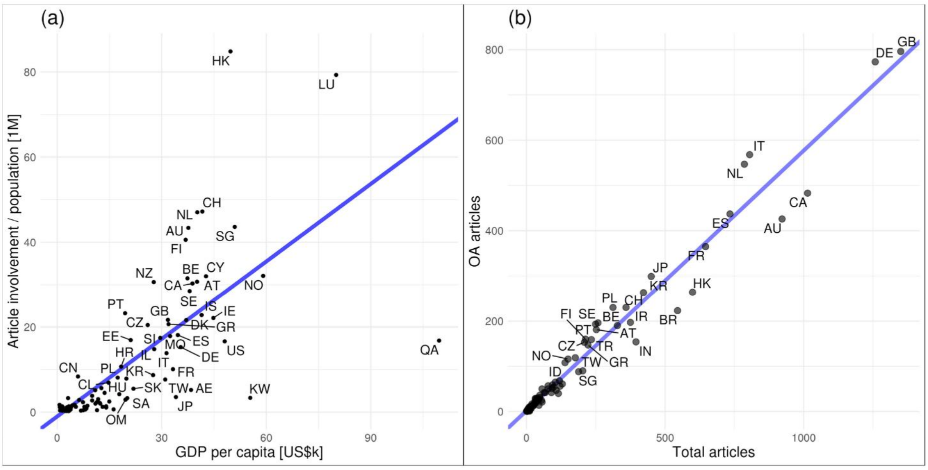

Figure 5. Standardizing efficiency of jurisdictions by relating economic activity (GDP per capita in thousand US$) with normalized article involvement (a); scatterplot of the relation of OA and total article involvement per jurisdiction (b). Labels shown correspond to the ISO 3166-1 alpha-2 standard.

Table 3 shows the most frequent jurisdiction-pairs that author GIScience articles together. Mainland China is found to collaborate most frequently with others (appearing in the five most frequent collaboration pairs). On the continent level, Figure 6 shows the strongest links between Asia, Europe and North America. Other continents participate in the international collaboration in much smaller rates. In fact, the most collaborative Asia–North America pair shared 572% more collaborations than the fourth, Asia–Oceania pair. However, this inequality is ultimately rooted in the unequal distribution of GIScience articles (see Figure 3).

About half of GIScience journals publish more international articles than the average. Figure 7 shows the distribution of journals based on the percentage of cross-border papers they publish. There is a 25% difference between the most and least international journal. Journals that are proportionally most international are JAG (42.7%), P&RS (42.2%), CEUS (40.2%) and GEIN (39.7%). On the other end, less than quarter of articles are a result of international collaboration in JGSA (23.3%), PE&RS (19.7%) and JSS (19.0%).

3.3. Journal metrics

Pairwise Spearman's rank correlations were calculated to assess the degree with which journal metrics correlate. A total of 52 correlation coefficients were calculated across all years and metrics. Coefficients range between 0.4 (between IF and SNIP in 2018) and 0.97 (SJR and Influ in 2022). Generally, there is a high level of correlation between journal metrics ($mean = 0.81$; $median = 0.86$), and only 6% of the coefficients are below 0.6. Correlation matrices are given in Tables S2–S6 in the Supplementary Material.

Figure 8(a) shows the ranking of each journal across years and metrics. Most journals ranked rather consistently between 2018 and 2022. To identify 'top movers', a difference between highest and lowest rank in CiteScore, IF, SJR and SNIP was calculated for each

Table 3. Top 15 jurisdiction (left) and continent collaborations pairs (right) in selected GIScience journals based on authors' affiliation.

	Jurisdiction 1	Jurisdiction 2	# of articles		Continent 1	Continent 2	# of articles
1	Mainland China	United States	1,262 [7.7%]	1	Asia	North America	2208 [13.4%]
2	Mainland China	Hong Kong	472 [2.9%]	2	Asia	Europe	1553 [9.4%]
3	Mainland China	United Kingdom	339 [2.1%]	3	Europe	North America	1224 [7.4%]
4	Canada	Mainland China	305 [1.8%]	4	Asia	Oceania	386 [2.3%]
5	Australia	Mainland China	204 [1.2%]	5	Europe	Oceania	322 [2.0%]
6	United Kingdom	United States	202 [1.2%]	6	North America	South America	207 [1.3%]
7	Mainland China	Germany	195 [1.2%]	7	Europe	South America	195 [1.2%]
8	Canada	United States	190 [1.2%]	8	North America	Oceania	181 [1.1%]
9	Mainland China	Netherlands	154 [0.9%]	9	Africa	Europe	120 [0.7%]
10	Australia	United States	123 [0.7%]	10	Africa	Asia	108 [0.7%]
11	Mainland China	Singapore	102 [0.6%]	11	Africa	North America	95 [0.6%]
12	Germany	United States	100 [0.6%]	12	Asia	South America	57 [0.3%]
13	Hong Kong	United States	99 [0.6%]	13	Oceania	South America	26 [0.2%]
14	Brazil	United States	99 [0.6%]	14	Africa	Oceania	21 [0.1%]
15	Mainland China	Japan	98 [0.6%]	15	Africa	South America	8 [0.0%]

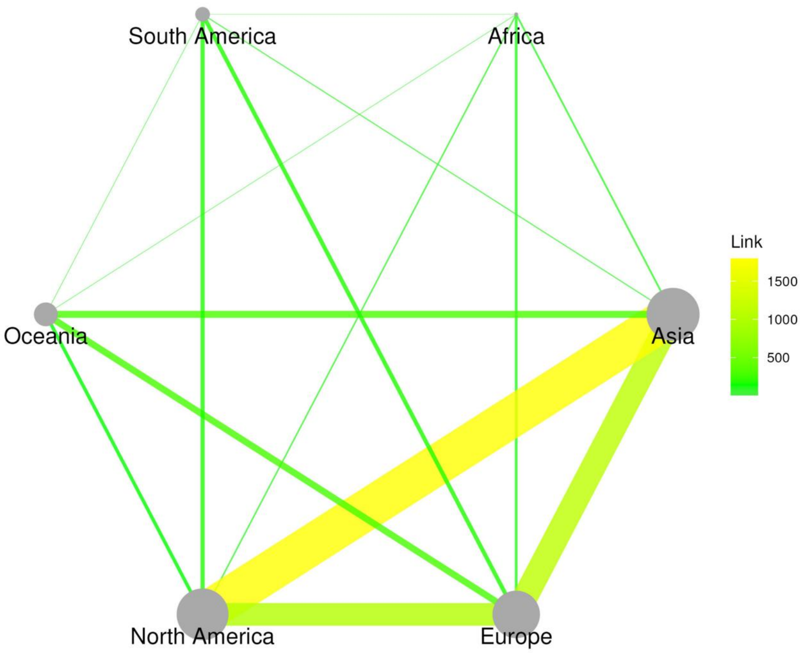

Figure 6. Collaboration network of articles in selected GIScience journals based on the continent of authors' affiliation.

journal. Seven journals (30%) climbed more than six places in CiteScore and IF rankings, while 8 and 11 for SJR and SNIP, respectively. AGIS, GSIS and JGSA were found to be a top-mover in all metrics, while CaGIS and PE&RS in three metrics. These journals showed the most rise, which can be attributed their young age and therefore missing metrics. For example, AGIS received its first IF only in 2022, which resulted in a jump from 24th (2021) to 8th (2022). Another way to look at the evolution of journals is comparing their ranks between 2018 and 2022. In this regard, seven journals kept or improved their initial rankings across all metrics. These were AGIS, C&G, GEAN, GSIS, JGSA, JOSIS and P&RS, while another three (CEUS, G&RS and JGS) improved in three metrics. Among the journals that declined in rankings across all metrics are APG, CaGIS, PE&RS and TGIS, followed by EPB, GEIN and IJDE losing positions in three metrics.

For the year 2022, I consider four additional metrics (Eigen, IF5yr, Imm and Influ) to construct a composite ranking of GIScience journals. This meta-ranking computes the arithmetic mean of ordinal rankings to capture more insights than a simple metric could provide. Figure 8(b) shows journals ordered by their composite ranking, along with bars showing lowest and highest ranks. The background is colored in a way to easily identify which quartile a journal falls in. Not surprisingly, the computed average rank shows high level of correlation with the individual metrics, with Spearman's correlation coefficients ranging from 0.77 (Imm) and 0.97 (SJR, IF5yr).

There are several ways to find similarly ranked journals. The most straightforward is dividing the ranking into quartiles (indicated by background colors in Figure 8(b), i.e. Q1: green, Q2: yellow, Q3: orange, Q4: red). Journals in the first quartile, which could be perceived as the most highly ranked category of journals, were P&RS (avg. rank: 1.0), JAG (3.0), CEUS (4.0) and IJGIS (5.5). On the lower end, SCC and TSAS (both 20.8),

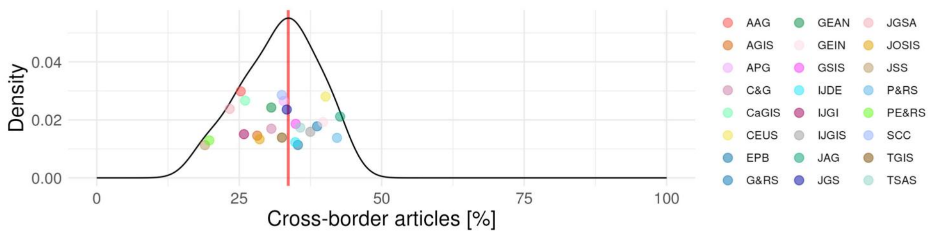

Figure 7. Journals and cross-border articles. The red vertical line is the % of international articles among all GIScience articles.

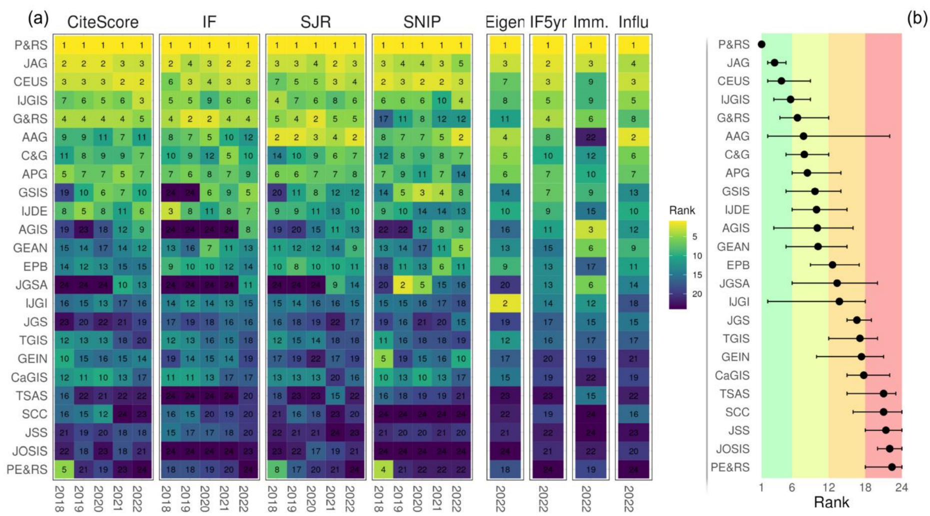

Figure 8. GIScience journal rankings between 2018 and 2022 for individual metrics (a); composite ranking score composed of metrics (year 2022) with bars indicating minimum and maximum ranks (b).

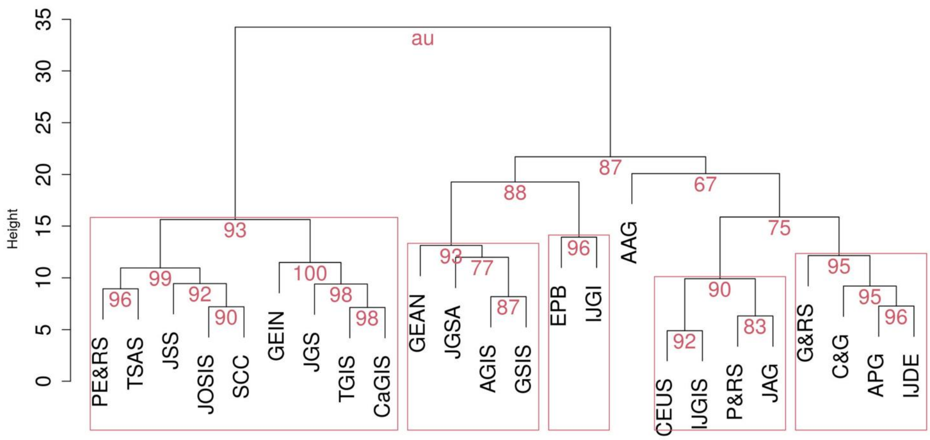

Figure 9. Hierarchical clustering of GIScience journals using eight journal metrics (IF, IF5yr, SJR, SNIP, CiteScore, Imm, Eigen, Influ) in 2022. Meaningful clusters ($AU \geq 90$) are highlighted in red rectangles.

JSS (21.3), JOSIS (21.8) and PE&RS (22.3) ranked at the bottom quartile. Another approach is to use agglomerative hierarchical clustering, which is shown in the dendrogram in Figure 9. Calculating AU with multiscale bootstrapping allows to find the most meaningful clusters. The results of a clustering are similar to the simple quartile approach. Clusters from most to least highly ranked are as follows:

1. CEUS, IJGIS, P&RS, JAG;
2. G&RS, C&G, APG, IJDE;
3. GEAN, JGSA, AGIS, GSIS;
4. EPB, IJGI;
5. PE&RS, TSAS, JSS, JOSIS, SCC, GEIN, JGS, TGIS, CaGIS.

The only journal that was not assigned a cluster is AAG, which can be attributed to its low rank in terms of immediacy index (20th out of 24th) compared to a mean ranking of 5.9 in all other metrics.

4. Discussion of results

The overall volume of GIScience publication has continued to rise, which follows previous studies analyzing GIScience publications between 1990 and 2020 (Biljecki 2016, Huang 2022, Wu *et al.* 2023). The geographic distribution based on the location of GIScience paper authors shows little change from previous studies. Compared to the period of 2000–2014 (Biljecki 2016), Mainland China rose to more prominence. These trends, however, are not unique to GIScience and were observed for science and engineering (S&E) fields in general (White 2021). Five economies among the top 10 worldwide producers of S&E research are underrepresented in GIScience research, namely India, Japan, Russia, South Korea and Russia. In place of these countries, Canada, Australia, the Netherlands, Spain and France are among the top 10 jurisdictions in terms of involvement in GIScience articles. The underrepresentation of some large economies (e.g. France, Germany and India) may be attributed to the availability of well-established, domestic, non-English language journals in these regions which were not included in this study, and are generally underrepresented in bibliometric and scientometric studies (Van Leeuwen *et al.* 2001, van Raan *et al.* 2011).

The concentration of GIScience research also suggests that there is a geographic bias against another group. Sixty-five jurisdictions were found to have not participated in GIScience publications in the dataset between 2018 and 2023. Biljecki (2016) found 75 countries excluded from the global discourse of GIScience. This suggests that the geographic bias has only been mitigated slightly in recent years. This underrepresentation is in particular strong against the Global South. This is again not specific to our field and is considered true to all scientific output (Collyer 2018). However, this also implies that GIScience is not more inclusive than other fields.

This is also supported by a strong association between a jurisdiction's income group and involvement in GIScience articles. In particular, publishing activity in GIScience decreases with income levels. It has to be noted, though, it is possible that authors from low-income regions prefer to publish in their local, non-English language outlets. Nevertheless, this still means that these countries are not part of the international collaboration in GIScience. Greater involvement of these underrepresented regions in the global GIScience collaboration would be an effective measure to compensate for smaller scientific communities and smaller resources (Confraria *et al.* 2017). In particular, Africa and South America are participating in cross-border publications at a smaller rate than other continents.

OA publishing was found to benefit authors from developing countries (Björk 2017), and this could be a way to mitigate the bias against the Global South. A commentary authored by ecology scholars explicitly notes that while OA would be beneficial, covering APCs to publish in top journals, is still a hardship for African scientists due to lack of funding and resources (Mekonnen *et al.* 2022). The average APC to publish in GIScience journals included in this study is almost $3000, which indeed can be difficult to cover without institutional support and established funding. Moreover, APC to publish OA in three of the top four GIScience journals are higher than the average, which presents further barriers to disseminate research from less developed countries in the most prestigious GIScience journals. Despite these potential barriers, these data did not confirm that jurisdictions that are underrepresented in GIScience research are also disproportionately represented in OA publishing. Nevertheless, high APCs foster inequalities (Williams *et al.* 2023), and while institutional support, fee-waivers, discounts and OA funds aim to mitigate these, some research suggests that these mechanisms can distort co-author networks (Edem *et al.* 2021, Borrego 2023). Therefore, a universal solution is still yet to be found. On the bright side, the proportion of OA articles in GIScience is on the rise, with the ratio of OA among all articles increasing approximately 3.9% every year paving the way toward a more inclusive GIScience. This increase aligns with an earlier (not GIScience specific) report that found accelerated growth in OA availability (from 2.4% in 2013) (Archambault *et al.* 2014). There is also evidence that GIScience research is shared on preprint servers, which helps the rapid dissemination of new knowledge. This practice plays an important role during crises and catastrophes, like the COVID-19 pandemic (Fraser *et al.* 2021), and GIScience can offer valuable insights in rapidly changing an geographically complex processes. Despite the potential benefits, preprints seem to have gained less traction outside physics, mathematics and computer science in general. Some concerns against preprints in the life sciences were low reliability and credibility and premature media coverage (Ni and Waltman 2024). This might apply to GIScience as well; however, the exact reasons why preprints have not gained much popularity in GIScience need further exploration.

The fluctuation in journal metrics and rankings within GIScience, as observed in this study, offers insight into the changing landscape of dissemination outlets. These movements, driven by factors such as citation frequency, IF and journal prestige, play a crucial role in shaping the perceived quality and influence of GIScience journals. A rise in a journal's ranking often correlates with increased visibility and credibility, potentially attracting higher-quality submissions. However, this dynamic also raises concerns about the overemphasis on metrics in valuing research, which might overshadow the intrinsic quality and innovation of the studies published. Nevertheless, this paper presented a comprehensive evaluation of journal rankings across several metrics. This structured analysis can serve as a guide for scholars in finding suitable outlets for their research.

In addressing the need for increased inclusivity and diversity in GIScience research, the following recommendations are offered based on the results presented in this study. First, there is a critical need to foster collaborations and partnerships that include researchers from underrepresented regions, particularly from the Global South. This can be achieved through targeted funding opportunities, mentorship programs and the establishment of international research consortia. Second, journals and funding bodies could incentivize studies that address region-specific challenges (e.g. as special issues) or are led by researchers from underrepresented areas. Another important step is enhancing access to GIScience education and training in these regions, therefore, building local research capacities. Initiatives, such as YouthMappers (Solís *et al.* 2018) and OSM Science (Grinberger *et al.* 2023), harnessing participatory mapping approaches could be a way to achieve greater inclusivity from underrepresented regions. Lastly, adopting OA models can democratize the dissemination of GIScience knowledge, making it more accessible to a broader, more diverse audience. These steps, collectively, would not only enrich the GIScience research ecosystem but also ensure that it resonates more closely with global needs and perspectives.

4.1. Limitations of the study

There are inherent limitations originating from the study design and other constraints. These are listed below:

- There is an apparent bias in the selection of GIScience journals. Sections 1.1 and 2.1 explain the challenges in identifying GIScience journals.

- Journal publications do not represent all GIScience research outputs as other outlets, such as conferences, workshops and books are also commonly used to disseminate research.
- GDP was used as an indicator to assess economic bias; however, it would have been more appropriate to use research expenditures, especially in GIScience; however, these data are not available for most countries for the study period.
- Language barriers and cultural factors could also influence publication habits, potentially skewing the analysis toward English-language publications and Western perspectives.
- Journal metrics are widely criticized as overvalued to measure the real impact of research, and there are initiatives aiming to place less emphasis on them (see e.g. The American Society for Cell Biology 2012).

5. Summary and future work

This paper analyzed selected GIScience journals and their publishing trends between 2018 and 2023. It assessed publication volumes, OA trends, as well as the geographic distribution of and international collaboration in GIScience journal publications. The paper also evaluated GIScience journals across eight commonly used metrics that aim to quantify the impact and quality of journals. A composite, meta-ranking was constructed using these metrics to provide a simple overview of the standing of GIScience journals. The main findings of the paper can be summarized as follows:

- *Growth in publication volumes*: There is a notable growth in the number of articles published in GIScience journals from 2018 to 2023, increasing from 2164 to 3174. However, this growth is attributed to a few journals that are growing at a higher rate.
- *Growth in OA publishing*: GIScience research is increasingly disseminated as OA. The study showed a consistent upward trend in OA publishing across the included journals, with OA publications increasing from 754 to 1961 between 2018 and 2023 (average 3.9% yearly increase).
- *Geographic disparity in international collaboration*: The Global South is underrepresented in GIScience research compared to more developed regions. This disparity highlights the need for greater inclusion and support for researchers in these regions.
- *Top movers and rank consistency*: Certain journals exhibited significant movements in their rankings based on journal metrics. For example, AGIS, GSIS and JGSA emerged as a top-mover in all metrics, showing the most growth. Seven journals consistently kept or improved their initial rankings across all metrics from 2018 to 2023.
- *Composite ranking and clustering of journals*: Using eight metrics, a meta-ranking of GIScience journals was established, which provides a more comprehensive view of each journal's standing. Journals were grouped into five groups of similar characteristics.

A key implication is the need to periodical revisit these trends to capture the dynamic nature of GIScience research and publication practices. Such follow-up studies would be important in tracking the evolution of the geographic distribution of research, international collaboration and the impact of OA policies. Additionally, future research could investigate the factors driving these trends, particularly the economic, technological and policy influences that shape GIScience publishing. Another promising area for exploration is the impact of new publishing platforms and formats, like preprint servers and digital repositories, on the dissemination and reception of GIScience research. This could provide more insights into how researchers can adapt their publication strategies to maximize impact and visibility in an increasingly digital and interconnected academic world. Another area for further exploration is open science principles, particularly how GIScience shares data and ensures reproducible and replicable research. Furthermore, the identity of GIScience should be investigated further to consider the different disciplines that are involved, trends and patterns in these, as well as scientific subjects that GIScience aims to address.

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No potential conflict of interest was reported by the author(s).

Notes on contributor

Levente Juhász is a Research Assistant Professor and the Assistant Director of GIScience at Florida International University. His research interests include understanding the data quality of user-generated content, user behavior in online communities, and spatial analysis of data from social media and other online platforms.

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Data and codes availability statement

Supplementary Material, including the data and code that support the findings of this study are available at the following location: https://doi.org/10.17605/OSF.IO/8ZXUD.

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