Accepted Manuscript

A scientometric analysis of selected GIScience journals

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This is an Accepted Manuscript of an article published by Taylor & Francis in the journal *International Journal of Geographical Information Science*, available online:
http://doi.org/10.1080/13658816.2015.1130831

Cite as:

Biljecki, F. (2016): A scientometric analysis of selected GIScience journals. *International Journal of Geographical Information Science*.

Abstract

A set of 12436 papers published in 20 GIScience journals in the period 2000–2014 were analysed to extract publication patterns and trends. This comprehensive scientometric study focuses on multiple aspects: output volume, citations, national output and efficiency (output adjusted with econometric indicators), collaboration, altmetrics (Altmetric score, Twitter mentions, and Mendeley bookmarking), authorship, and length. Examples of notable observations are that 5% countries account for 76% of global GIScience output; a paper published 15 years ago received a median of 12 citations; and the share of international collaborations in GIScience has more than tripled since 2000 (31% papers had authors from multiple countries in 2014, an increase from 10% in 2000).

Keywords: Scientometrics; GIScience; bibliometrics; altmetrics; social media

1 Introduction

Geographical information science (GIScience) is a rapidly evolving discipline with thousands of papers spread over dozens of journals and conferences. As a result of the growing number of publications it is increasingly difficult to keep up with trends. An approach to understand patterns and to evaluate the impact of scientific publications is to employ techniques established by scientometrics, a discipline dealing with quantitative aspects of science and technology (Hood and Wilson, 2001; Pouris, 2012). While many scientometric studies have been carried out in other disciplines (Section 2), this work identifies that GIScience lacks a comprehensive analysis. The goal of this paper is to bridge this gap by using scientometric techniques to conduct a comprehensive, longitudinal and systematic survey study on the GIScience research production in the last 15 years (period 2000–2014).

The paper first presents a list of prominent GIScience journals to draw a large sample of papers that represents the relevant GIScience body (Section 3). This task has been hampered by the fact that GIScience is not a homogenous and strictly defined discipline, and that there is no consensus among GIScience researchers about the relevant publication outlets. This list can also be considered as a by-product of this study.

The analysis provides several insights which may aid GIScience researchers, educational institutions, and policy makers in understanding the development of the field. Several aspects are investigated, mostly by employing conventional methods (Section 4), such as:

- How many papers are published in relevant GIScience journals, and is their annual output increasing?
- How are publications distributed among countries, and which countries are currently producing most papers? How do countries perform when demographic or econometric indicators are taken into account?

- How much attention do GIScience papers receive in social media, how does that compare to other disciplines, and do highly mentioned papers capitalise this attention in citations?
- How many publications are a result of an international collaboration, and which entities collaborate most? Do countries with more experience in international collaboration tend to produce papers with a higher impact?
- What are the most cited papers in GIScience, and which papers are most frequently found in researchers' collections? Is there a correlation between the two?

2 Related work

Several similar studies have been carried out in other disciplines, e.g. cloud computing (Heilig and Voss, 2014), neurology (Gupta *et al.*, 2014; Garnett *et al.*, 2013), dentistry (Yang *et al.*, 2001), human geography (Wang and Liu, 2014), alternative medicine (Chiu and Ho, 2005), epidemiology (Dannenberg, 1985; Ugolini *et al.*, 2007), remote sensing (Zhuang *et al.*, 2013; Peng *et al.*, 2015), nursing (Estabrooks *et al.*, 2004), clinical radiology (Rahman *et al.*, 2005), knowledge management (Serenko and Bontis, 2004; Gu, 2004), economics and business (Nederhof and van Raan, 1993; De Bakker *et al.*, 2005), tourism (Michael Hall, 2011), wastewater research (Zheng *et al.*, 2015), genetics (Sangam *et al.*, 2013), and earthworm research (Xiang *et al.*, 2015).

While evaluating science has been thoroughly addressed in many disciplines, to the best of my knowledge there is a lack of a general and comprehensive scientometric study in GIScience. This paper aims to carry out a thorough scientometric analysis focusing on multiple aspects, with an addition of altmetric indicators.

It is beneficial to mention other scientometric and bibliometric work related to GIScience, mostly focused on a specific publication aspect.

Tian *et al.* (2008) record all 1997–2006 papers in journals indexed by the Institute for Scientific Information (ISI) that contain the term *GIS* in the title, abstract, or keywords. The research indicates that the journal with most such occurrences is the *International Journal of Geographical Information Science*. However, their work is too liberal on the inclusion criterion: it does not distinguish between GIScience papers and those that only use GIS as a tool, considering that the analysis includes 1918 journals belonging to all 202 different discipline categories determined by ISI. This paper is focused on GIScience, taking into account only well-established and well-known sources that publish predominantly GIScience research papers (Section 3).

Parr and Lu (2010) present a study on trends and patterns of research activities in GIScience in the period 1997–2007, e.g. connections between GIScience researchers, and the productivity of departments within several research themes. Sun and Manson (2011) carry out a scientometric social network analysis to explore the authorship aspect of GIScience papers, e.g. degree of connected authors, and number of multi-author papers. Wei *et al.* (2015) mapped the GIS knowledge domain by identifying the most important papers and analysing how GIScience research interests evolve over time. Skupin (2014) and Zhan *et al.* (2014) conduct scientometric studies on the impact of the work of Professor David M. Mark, a renowned GIScientist. Old (2001) investigates the use of spatial analysis in scientometrics. Caron *et al.* (2008) and Kemp *et al.* (2013) present ranked inventories of GIScience journals (more on these initiatives in the next section). Blaschke and Eisank (2012) carry out a scientometric analysis on the relation of terms *GIScience* and *GIS* in literature. Stojanovski *et al.* (2015) investigate the coverage of mapping science journals by 14 bibliographic databases, such as Web of Science and Scopus. Gutiérrez and López-Nieva (2001) study the internationalisation of journals in geography, which is relevant considering that the work covers a few journals that might be of interest to GIScientists. Duckham (2015) uses a citation and keyword analysis to identify a shared core of GIScience expertise.

3 Methodology

3.1 Selecting GIScience journals

Since it is not possible to capture all GIScience literature that exists, relevant GIScience journals should be selected and their inclusion is an important part of the methodology. Although scientometric analyses may be applied to any type of publication, analyses such as this one usually consider only journals for consistency. Conference proceedings are excluded also for technical reasons (e.g. occurrence at irregular intervals, not all proceedings of the same series are indexed, and difficulties with retrieving data). This should by no means imply the depreciation of the importance and contribution of papers published in GIScience conferences.

Before going into more details in the selection of GIScience journals, an overview of encountered barriers is given, followed by related work:

- GIScience is non-homogeneous, multidisciplinary, without clear boundaries, and arguably without an authoritative definition. This uncertainty propagates to defining what is exactly a GIScience journal (Caron *et al.*, 2008), and a consensus on the list of the list of GIScience journals cannot be reached (Kemp *et al.*, 2013). There have been several discussions on the demarcation of GIScience (Goodchild, 1992; Mark, 2003; Reitsma, 2013; Goodchild, 2009; Wright *et al.*, 1997), and such deliberations have been taken into account.
- ISI does not contain a GIScience discipline category, thus the usual approach of scientometric researchers (e.g. Amat (2008); Yu *et al.* (2006); Dong *et al.* (2006); Sugimoto *et al.* (2013)) who select the corresponding ISI category cannot be used. For instance, *GeoInformatica*, without debate a GIScience journal, is assigned to two categories: (i) Computer Science/Information Systems; and (2) Geography/Physical; most of the journals in these two categories are not related to GIScience.
- GIScientists publish also in journals in other disciplines (Kuhn and Brox, 2011). For example, journals *Building and Environment* and *Computers & Graphics* have published papers that can be considered in the scope of GIScience (for examples see (Tashakkori *et al.*, 2015) and (Germs *et al.*, 1999), respectively), but that does not categorise them as GIScience journals. It is uncertain where to place a threshold on how many such papers a journal has to

publish in order to be considered a GIScience source (and is such a thing possible considering that the term *GIScience paper* is also fuzzy).

- Multidisciplinary journals are interesting to mention as a relatively new uncertainty. For instance, PLOS ONE has published a number of GIScience papers (e.g. (Kang *et al.*, 2015)). They are not considered, since their inclusion would bias the results.

Deriving a list of relevant journals in GIScience and related fields has already been an effort of several researchers. An early example is the work of Salichtchev (1979) who compiled a list of cartographic-geodetic journals.

The study of Caron *et al.* (2008) ranks several GIScience journals based on a survey, and it provides an important foundation for this research. The ranking contains 21 ISI and 23 non-ISI journals, which have been selected by an international questionnaire. The list is generous with the notion of a GIScience journal, hence arguably less related journals have been included.

Kemp *et al.* (2013) carry out a similar study, resulting in journals grouped in a few categories that reflect their reputation in the GIScience community. Researchers conclude their survey by stating that they have not reached a consensus among GIScientists about the list and ratings of journals.

Frančula *et al.* (2013b) have derived an extensive list of 105 mapping journals. A journal was considered relevant to mapping sciences if more than half of its contents covered at least one branch of geodesy (cartography, photogrammetry and remote sensing, marine, satellite and physical geodesy, applied geodesy and geomatics). While the list is not focused on GIScience, it has been carefully considered. In a succeeding research, Frančula *et al.* (2013a) expose 35 non-mapping ISI journals which could be of interest to mapping scientists. The link was established through checking the *Aims and Scope* of a journal, and by searching titles published in each journal three years prior to the research. The research lists five journals that could be of interest to GIScientists, and these have been taken into account.

Duckham (2015) identifies four core (leading) GIScience journals, which have been included in this research. Furthermore, the research points out that determining the corpus of GIScience journals is inevitably subjective, owing to increasingly blurred lines between disciplines.

The research of Gutiérrez and López-Nieva (2001) focuses on geography, but it contains a few journals that are of interest in the scope of this work.

Finally, it is important to note that a few research groups maintain lists of preferred GIScience journals on their websites. For instance, my research group at the TU Delft curates a public list* of journals that we consider when preparing a manuscript. Such lists† have also been found as valuable input when selecting the journals.

As it can be expected, there are significant discrepancies between all the analysed inventories, hence an authoritative list of GIScience journals that can be borrowed for this research does not

*`https://3d.bk.tudelft.nl/journals/`; last accessed on 29 Nov 2015.

†Another example is the list maintained by the Cartography and Geovisualization Group at Oregon State University, available at `http://cartography.oregonstate.edu/journals.html`; last accessed on 29 Nov 2015.

exist. Analysing related work revealed that there is a consensus about only a few core GIScience journals, but restricting this analysis to such small set of journals would not be interesting. Furthermore, within this project several attempts have been made to derive objective criteria for the selection of journals, but without success, mostly due to the indistinct demarcation of GIScience, and mixed content of journals (e.g. journals that publish GIScience papers along with papers from other geomatics disciplines such as hydrography). Consequently, it was decided to derive a new list of journals by combining inventories found in related work, with some modifications (e.g. exclusion of predominantly remote sensing journals).

As this part of the methodology cannot be considered as *exact science*, one should accept some subjectivity and personal choice here. Many researchers in related scientometric analyses (Section 2) confronted with the same problem take a degree of liberty in the selection of journals they consider to represent a discipline, hence this approach is in line with scientometric practices. Furthermore, the aforementioned related research papers, despite some of them using scientific methodologies (e.g. using the Delphi method), are inherently based on personal preference.

Nevertheless, the obtained list of journals has a high degree of overlap with the results of related work, and it captures a large share of GIScience output which is adequately significant and sufficiently large to draw conclusions:

1. Annals of the Association of American Geographers (AAG)
2. Cartography and Geographic Information Science (CaGIS)
3. Computers & Geosciences (C&G)
4. Computers, Environment, and Urban Systems (CEUS)
5. Environment and Planning B: Planning and Design (EPB)
6. Geographical Analysis (GEAN)
7. GeoInformatica (GEIN)
8. GIScience & Remote Sensing (G&RS)‡
9. International Journal of Applied Earth Observation and Geoinformation (JAG)
10. International Journal of Digital Earth (IJDE)
11. International Journal of Geographical Information Science (IJGIS)
12. ISPRS International Journal of Geo-Information (IJGI)
13. ISPRS Journal of Photogrammetry and Remote Sensing (P&RS)
14. Journal of Geographical Systems (JGS)
15. Journal of Spatial Information Science (JOSIS)

‡Formerly (before 2004) *GIScience & Remote Sensing* had been known as *Mapping Sciences and Remote Sensing*. The old name has been taken into account when retrieving the data of papers.

16. Journal of Spatial Science (JSS)
17. Photogrammetric Engineering & Remote Sensing (PE&RS)
18. Photogrammetrie, Fernerkundung, Geoinformation (PFG)
[Journal of Photogrammetry, Remote Sensing and Geoinformation Processing]
19. Spatial Cognition and Computation (SCC)
20. Transactions in GIS (TGIS)

A few selected journals are not principally GIScience outlets. An example is the ISPRS Journal of Photogrammetry and Remote Sensing (P&RS). As the title suggests, it is focused towards photogrammetry and remote sensing, however, it has been known to have published a significant amount of relevant GIScience papers in the past. For instance, the papers of Gröger and Plümer (2012) and of Boguslawski *et al.* (2011), are works of arguably high relevance to the GIScience community that have been published in P&RS (moreover, both papers have received the best paper award in the year in which when they were published; see (Vosselman, 2012) and (Lichti, 2013), respectively, for details). Therefore, overlooking such sources of GIScience literature would not be just.

3.2 Acquisition of data

Data of papers have been retrieved from Scopus through its application programming interface (API). Scopus includes citations from a wide range of publications, which gives a comprehensive picture about the impact of papers. For each paper data such as DOI, Scopus citation count, affiliations, were retrieved. Altmetrics data (explained in more detail in Section 4) were acquired through the APIs of Altmetric and Mendeley. All data were collected on 23 September 2015.

There are some exceptions caused by limitations: (1) IJGI is not yet included in Scopus; and (2) volumes of IJDE published in 2008 and 2009 are not indexed by Scopus. These volumes were supplemented from the publishers' records. Since a large part of the methodology presented in this paper relies on data from Scopus (e.g. received citations and affiliations of authors), most of the analyses do not cover IJGI, and IJDE papers published in 2008 and 2009. These two exceptions amount to 1.6% of the total number of analysed papers.

3.3 Selection of papers

All papers included in journal issues published from 2000 to 2014, were considered, except records such as book reviews, corrigenda, list of reviewers, etc. Furthermore, only papers with a cover date in the range 2000–2014 were considered. Therefore an additional filter was set to disregard papers that are not yet published in an issue (i.e. "in press", "ahead of print").

3.4 Normalising the output and citations

Most of the analyses presented in this paper deal with comparing the number of papers and the citations with several other indicators. Here it is important to clarify different measures that are used in this study.

In general, multiauthor and multinational contributions, constitute a problem in measuring the scientific output as there are different approaches to allocating credits (Nederhof and Moed, 1993; Kim and Kim, 2015). For instance, a multinational publication authored by three people with addresses in three countries can be credited as one publication to each, or as a third per each country/author. In fact, there are many different approaches how to calculate the researcher's (or country's) number of publications, e.g. assigning one full score to each author, assigning a score only to the first author, distributing a fractional score ($\frac{1}{n}$) to each author, and assigning a different score based on the order of authors (Cole and Cole, 1981; Van Hooydonk, 1997; Egghe *et al.*, 2000). Unless noted otherwise, in this paper fractional counting is used, i.e. the scores are uniformly distributed among participating authors and affiliations.

The multitude of different approaches to credit contributions entails different approaches to account the received citations. The citations are treated in the same manner, unless noted otherwise. For instance, a citation to a paper originating from three countries, is credited as a third of a citation for each.

This is not the only uncertainty when it comes to citations. Citation takes time, and age significantly influences the number of citations per publication. Therefore it is meaningless to directly compare citations of two papers published with a significant temporal distance (e.g. one published in 2013 and other in 2000). In order to suppress this chronological bias, in some instances the normalised citation impact index (NCII) is used: the number of citations of a publication is divided by its age in years (Serenko and Bontis, 2004). This measure gives a more realistic view on the impact and contribution of a paper not misrepresented by its age.

Furthermore, in analyses such as this one it is a practice to exclude self-citations, as they introduce bias in measuring the impact of a publication (MacRoberts and MacRoberts, 1989; Glänzel and Thijs, 2004a). A self-citation is defined as a citation in which the citing and the cited paper have at least one author in common (Aksnes, 2003; Hyland, 2003). All citation counts and analyses presented in this study exclude self-citations.

Finally, due to the usually skewed distribution of citations, medians are computed instead of means when giving aggregated results, e.g. average number of citations per paper. This topic has been discussed in Calver and Bradley (2009) and Vaughan and Shaw (2008).

4 Analysis and findings

The number of analysed papers, i.e. those that satisfy the criteria in Section 3.3, is 12,436.

Table 1: GIScience output of selected journals and impact by year.

Year	P	J	C	$\tilde{C}^a$	$\widetilde{NCII}^a$	IP	IP^b [%]	Countries	NC^c
2000	537	14	13591	12.0	0.8	54	10.0	46	
2001	510	14	13336	11.5	0.8	33	6.5	45	13
2002	571	14	16705	13.0	1.0	64	11.2	51	11
2003	579	15	16347	13.0	1.1	81	14.5	48	6
2004	599	16	18332	11.0	1.0	119	19.9	53	5
2005	625	16	14593	12.0	1.2	112	18.0	52	6
2006	703	16	16797	12.0	1.3	138	19.6	51	2
2007	675	16	12687	10.0	1.3	170	25.2	62	5
2008	748	17	11469	9.0	1.3	165	22.7	64	3
2009	920	18	10997	7.0	1.2	202	22.7	68	6
2010	922	19	10771	6.0	1.2	265	28.8	71	6
2011	1049	19	8387	5.0	1.3	278	26.5	68	2
2012	1342	20	7167	3.0	1.0	381	28.8	81	3
2013	1299	20	4055	2.0	1.0	323	26.0	75	3
2014	1357	20	1820	1.0	1.0	402	31.3	78	2
All	12436	20	177054[c]	5.0	1.0	2722	22.7	119	

Key: P—Publications; J—Journals (active); C—Citations; IP—International papers—publications with affiliations from more than one country; NC—"New countries" (appearances of countries not recorded before in the sample).
[a] Median value.
[b] In calculating the ratio, publications which are not included in Scopus were subtracted from the denominator.
[c] The total number of citations when including 29067 self-citations is 206121.

The quantitative results are presented in a series of tables and figures, which are divided into different categories, such as journals, national aspect, and authorship to describe statistics of publications within a journal, country, etc. Some findings are given only graphically because of the limited space. Further, in order to compact the results, some results are given together in tables, but are discussed disjointedly.

4.1 Output and impact of the selected journals

Table 1 and Figure 1 show the volume of papers in the observed period, decomposed by the year of publication. Output has grown since 2000 — it has more than doubled. The number of journals increased, but that is not the sole factor of the growth of the output — many journals publish more

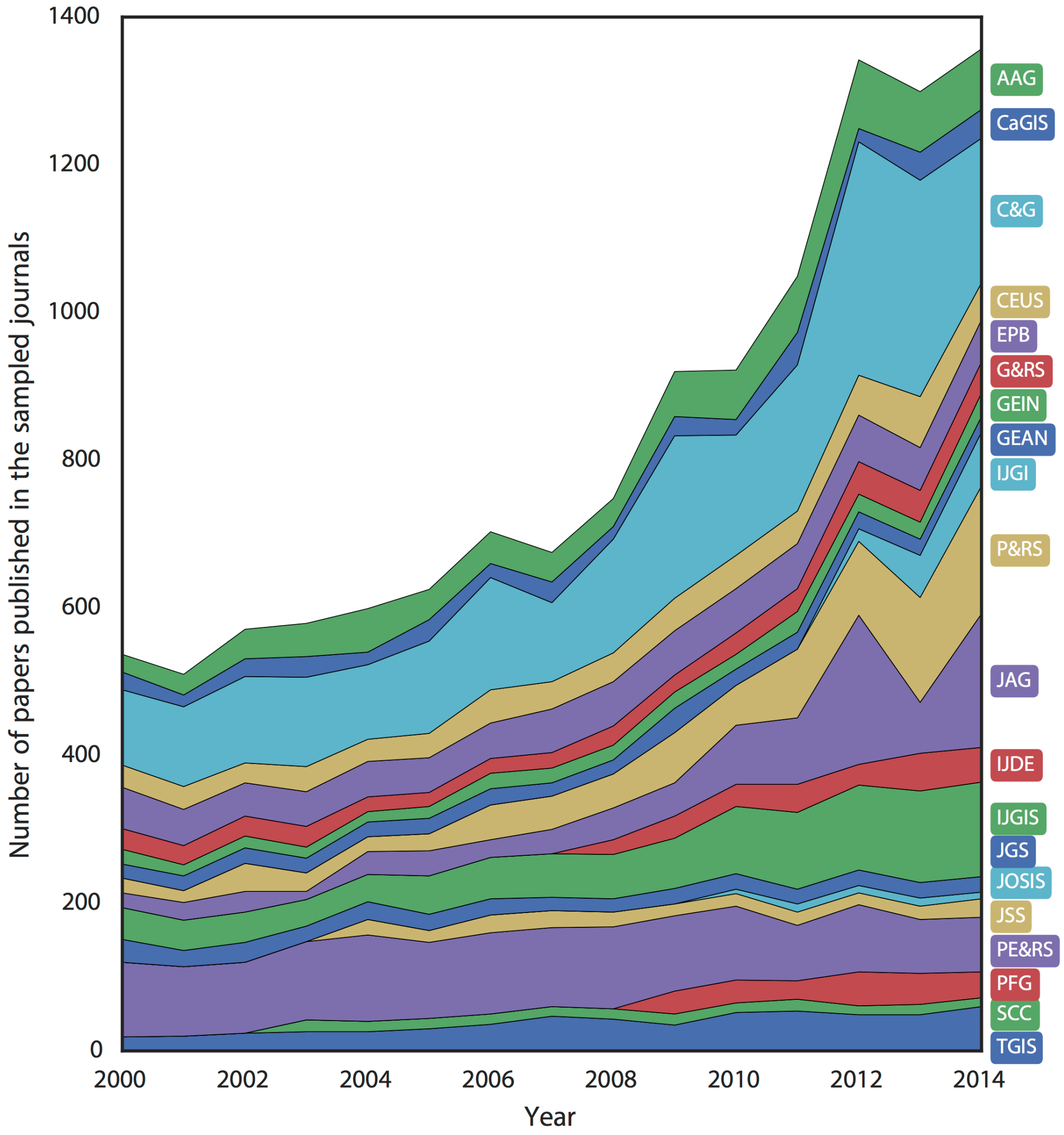


Figure 1: Publication output by the covered GIScience journals during the 15 year period analysed by the study.

papers than before. It appears that the output reached its peak in 2012 and in the last two years the volume fluctuated less than in the period from 2000 to 2012 (notice the surge from 2011 to 2012).

Papers published in these 15 years have so far attracted 177,054 citations, as tracked by Scopus. The median number of citations per paper is 5, and when normalised with its age it corresponds to a median NCII of 1.0 (the means are 14.5 and 2.1, respectively, indicating the skewness of the distribution of citations, and hence promoting the use of medians).

4.2 Journals

Figure 1 and Table 2 decompose the output volume by journal. The first observation is that journals substantially differ in the number of papers published (e.g. a fifth of papers have been published in C&G), and also their output may not be stable (cf. JAG in 2012 and in 2013). Furthermore, new journals (e.g. PFG and IJGI) are quick in attracting a number of papers comparable to journals with a longer tradition (e.g. in its inception in 2009, PFG published 31 papers, in comparison to 22 of the long-running GEIN). The introduction of new journals, which have quickly attained a noticeable share, indicates the strong supply of GIScience papers in the past few years.

Besides the volume decomposed by journals, it is important to analyse the impact of a journal, i.e. whether the share of received citations follow the share of published papers. In relation to this, it is interesting to investigate how mean citations correspond to the impact factor (IF), considering that the relation between IFs and citations has been weakening in the past 25 years (Lozano *et al.*, 2012). Table 2 contains the share of citations with the mean§ NCII per paper. It shows that there are deviations between the two values. AAG has the most favourable ratio between the share of citations and share of papers (it accounts to 11.3% of citations in comparison to 6.6% published papers). Since the selected journals do not constitute a closed system (Scopus tracks citations from thousands of other sources), favourable ratios might indicate a wider reach of journals. Such difference is to an extent reflected in the IF of the journal, but this study provides a longer period of analysis (in comparison with the 2-year window of the IF (Garfield, 1972)), and a direct comparison between the share of papers and citations. It shows that journals with a comparable IF might differ in the average number of citations they have received in the past, however, in general it follows the most recent IF ($r = 0.658$). IFs go up and down, and the average NCII per paper may give a more stable figure of the impact papers published in a journal have attained in the past.

4.3 A closer look on citations and impact

In this section, citations are examined in more detail. Figure 2 shows the distribution of citations per paper. To a degree there is an inequality in citedness, since the top 1% cited papers account

§In this particular computation the mean value has been used as an exception, due to the nature of the IF, which is calculated as the sum of citations divided by the number of papers.

Table 2: Output and impact by journal.

Journal	P	P [%]	P/Year	C	C [%]	$\overline{\text{NCII}}$	IF[a]
AAG	819	6.6	55	19706	11.3	3.0	2.291
CaGIS	388	3.1	26	3584	2.0	1.2	0.944
C&G	2473	19.9	165	30284	17.1	1.8	2.054
CEUS	612	4.9	41	10435	5.9	2.4	1.537
EPB	818	6.6	55	11102	6.3	1.6	0.983
GEAN	324	2.6	22	4810	2.7	1.8	1.543
GEIN	306	2.5	20	4131	2.3	1.6	0.745
G&RS	427	3.4	28	1857	1.1	1.0	1.770
IJGI[b]	147	1.2	49				
P&RS	910	7.3	61	21131	11.9	4.1	3.132
JAG	915	7.4	61	10965	6.2	2.6	3.470
IJDE[c]	244	2.0	35	1019	0.6	1.7	3.291
IJGIS	1055	8.5	70	17345	9.8	2.2	1.655
JGS	330	2.7	22	4029	2.3	1.4	1.500
JOSIS[b]	47	0.4	9	288	0.2	1.7	
JSS	214	1.7	19	588	0.3	0.5	0.588
PE&RS	1460	11.7	97	28260	16.0	2.1	1.608
PFG	210	1.7	35	361	0.2	0.5	0.733
SCC	167	1.3	14	1439	0.8	1.1	0.857
TGIS	570	4.6	38	5720	3.2	1.4	1.398
All	12436	100.0	829	177054	100.0	2.1	1.672

Key: P—Publications; C—Citations received.
[a] Impact Factor 2014 according to the 2015 Journal Citation Reports (Thomson Reuters, 2015).
[b] Citation count not available (not indexed by Scopus), and/or impact factor not yet available (not indexed by ISI).
[c] 50 papers published in 2008 and 2009 are not indexed by Scopus, and the calculation of the mean NCII has been adjusted (194 papers).

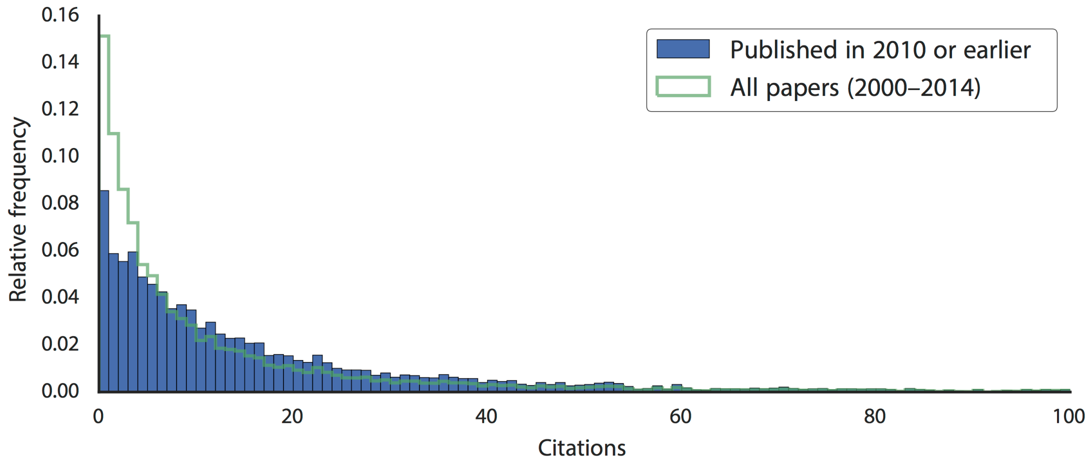


Figure 2: Distribution of citations from publications indexed in Scopus. Papers which received more than 100 citations represent less than 2% of the population, and are not shown here.

for 17.9% citations (31753) (percentile rank of score). The 99th percentile is at 133 citations.

In order to differentiate between old and new papers (age bias), the histogram shows the distribution of mature papers (published in or before 2010) separately from all papers. Results indicate that 8.3% of such papers have not yet been cited. As a comparison, 24.7% new papers (published after 2010) are uncited.

While it is possible that there are GIScience *sleeping beauties* awaiting a delayed recognition, papers not cited in 15 years after publication are unlikely to ever receive a citation (Glänzel *et al.*, 2003; van Raan, 2004). The absence of citations differs substantially between disciplines (Ghosh, 1975; Stern, 1990; Egghe *et al.*, 2011; Schwartz, 1997; Larivière *et al.*, 2009), and GIScience publications have a favourable result over most disciplines, e.g. demographics where 24% papers are uncited after 10 years (Dalen and Henkens, 2004). A closer look has been taken on uncited and seldom cited papers. Keywords of such papers have been analysed, and no pattern has been found, indicating that the uncitedness may not be topic-related.

On a related note, the rate of self-citation for the sampled publications is 14.1% (cf. to general medicine at 6%, a cross-disciplinary average of 40%, and mathematics at 44% (Kulkarni *et al.*, 2011; Glänzel and Thijs, 2004b)).

The citations have then been analysed by the year of publication. Figure 3 illustrates the average citedness per year of publication, and reinforces the decision of using the NCII metric. Older papers are generally in a better position to accumulate more citations, and NCII attempts to remove the bias. Further, the figure suggests that after 10 years papers start to fall into disuse. Such obsolescence is a usual occurrence in other disciplines (Egghe *et al.*, 1992).

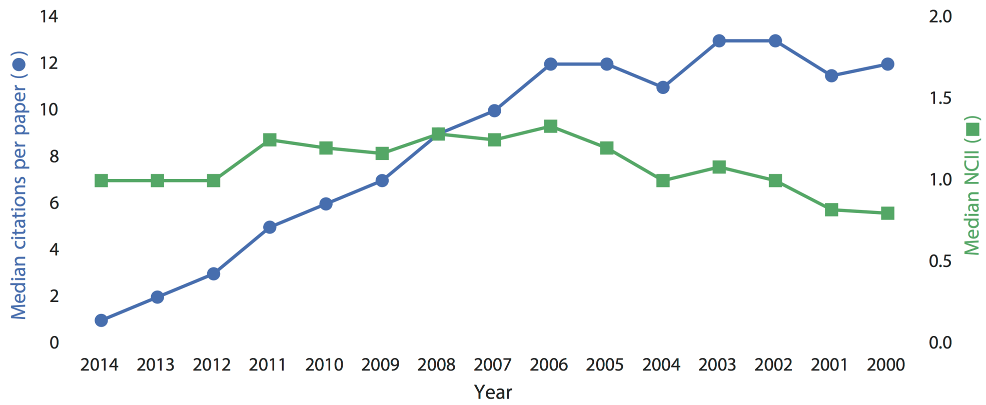


Figure 3: Mean number of Scopus citations for papers published in a year. Note that the x-axis is inverted to indicate ageing.

While most of the findings have been related with other disciplines, the citedness of GIScience papers is avoided to be compared to other disciplines, since the comparison between disciplines has been criticised and it is subject to significant bias (Abramo *et al.*, 2012; Dorta-González and Dorta-González, 2013).

Finally, Table 3 outlines the most cited papers in the observed sample, ordered by NCII. Most of these papers have been featured in journals publishing remote sensing papers (i.e. PE&RS and P&RS), possibly manifesting a wider audience that such topics attain.

4.4 Origin of publications and national aspect

For each publication the affiliation(s) of authors were recorded, and allocated a publication score and citation. This section analyses the output by affiliation: city and country. The reason why cities rather than institutions (e.g. universities) have been used is that the affiliations are not consistent in the data set (e.g. universities may have multiple designations), and the most granular classification that is reliable is the level of a city. Such analysis is important for a number of reasons, for instance, the share of papers and citations of an affiliation (e.g. country) may indicate its contribution to GIScience, and their longitudinal development may give insights on the rate of the development of GIScience in a country.

Figure 4 gives an overview of the international aspect: the number of countries behind publications per year. It shows that the each year new countries *debut*, and also the number of participating countries is continuously increasing, suggesting the growth of internationalisation of GIScience.

Table 3: Top 10 papers published in the covered journals in the observed period, ranked by the normalised received citations.

	Publication	Journal	NCII[a]	C[b]
1.	Blaschke (2010)	PR&S	168.6	843
2.	Benz *et al.* (2004)	PR&S	94.8	1043
3.	Fry *et al.* (2011)	PE&RS	94.8	379
4.	Mountrakis *et al.* (2011)	PR&S	77.5	310
5.	Homer *et al.* (2004)	PE&RS	68.1	749
6.	Rabus *et al.* (2003)	PR&S	59.8	706
7.	Pawlowicz *et al.* (2002)	C&G	57.8	752
8.	Anselin *et al.* (2006)	GEAN	57.2	515
9.	Blaschke *et al.* (2014)	PR&S	57.0	57
10.	Parker *et al.* (2003)	AAG	55.3	663
		Median of all papers	1.0	5

[a] NCII—Normalised Citation Impact Index (Serenko and Bontis, 2004): number of citations divided by age [years since published].
[b] Scopus citations until 23 September 2015, excluding self-cites.

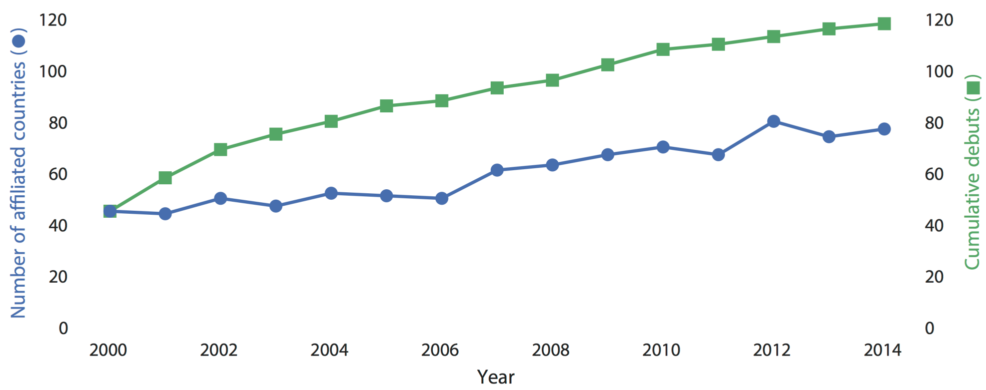


Figure 4: Affiliated countries per year, and the appearance of new *participants*.

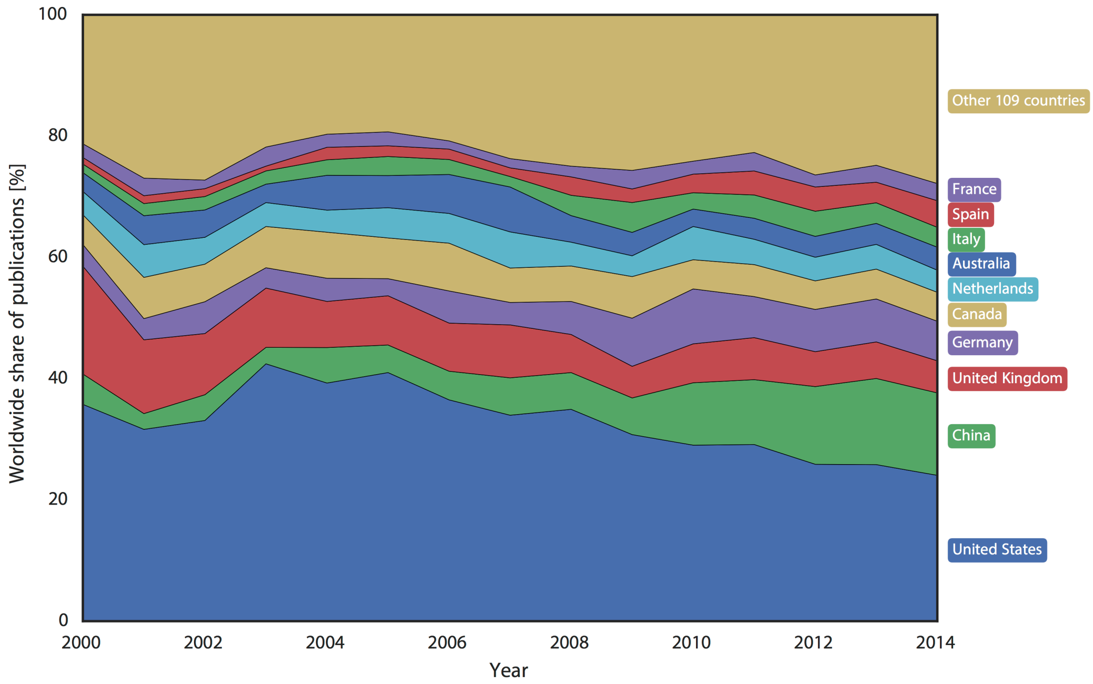


Figure 5: Longitudinal share of the output of top 10 countries and the rest of the world.

Total output and distribution

Table 4 illustrates the output by country and city, and Figure 5 shows the temporal trend of the share of output by country and by year. It is important to note that the ranking of cities does not represent the ranking of co-located universities, because of the potential multiplicity. For instance, Beijing ranked first, but it hosts multiple universities, agencies and state laboratories that are active in GIScience. However, such analysis may help identifying global GIScience centres.

The data show that 10 countries dominate GIScience: they produce more than three quarters of the volume. This is in accordance with other disciplines (Chiu and Ho, 2005). Furthermore, it shows some longitudinal differences between countries. The decreasing output share of the US (highest ranked) seems to be gradually compensated by China (2nd ranked).

However, note that while the share of some countries has dropped in the analysed period, this does not necessarily mean that the number of papers decreased in such cases, considering that the volume of papers is rising (cf. Figure 1 and Table 1, and see the trend in Table 5), e.g. consider the example of the United States (since 2000 to 2014 drop in share from 36% to 24%, but rise in the number of publications by 69%). On the other hand, China's output is rising substantially both absolutely and relatively (in the same period from 25.5 to 174 papers; i.e. 582%). The only major player that has experienced a decline in the output, and especially in the share, is the United Kingdom. These findings appertain to the trends in other disciplines and they have been a topic

Table 4: Top 15 countries and cities, ranked by the number of published GIScience papers in the sample (fractional distribution), and a comparison with the share of received citations.

	Country	P	P [%]	C [%]	City	P	P [%]	C [%]
1.	United States	3803.6	31.3	38.6	Beijing, CN	348.8	2.9	1.8
2.	China[a]	1038.3	8.6	5.6	Wuhan, CN	196.9	1.6	0.9
3.	United Kingdom	914.8	7.5	8.3	London, UK	167.2	1.4	1.9
4.	Germany	713.2	5.9	6.6	Enschede, NL	152.9	1.3	1.3
5.	Canada	699.0	5.8	7.2	Melbourne, AU	150.8	1.2	1.3
6.	Netherlands	521.9	4.3	4.8	Hong Kong, CN	126.9	1.1	0.9
7.	Australia	508.8	4.2	3.6	Columbus, US	123.5	1.0	1.5
8.	Italy	377.2	3.1	2.5	Santa Barbara, US	121.5	1.0	1.9
9.	Spain	330.8	2.7	1.5	Zurich, CH	110.5	0.9	1.2
10.	France	287.4	2.4	2.4	Washington[b], US	100.4	0.8	0.9
11.	Japan	211.0	1.7	1.2	Delft, NL	98.5	0.8	0.9
12.	India	183.2	1.5	1.0	Toronto, CA	96.2	0.8	0.8
13.	Switzerland	180.0	1.7	1.6	State College[c], US	91.4	0.8	1.1
14.	Austria	147.4	1.2	1.8	Vienna, AT	87.6	0.7	0.7
15.	Brazil	128.6	1.1	0.8	Tehran, IR	85.3	0.7	0.3
…	Others (104) (87.4% countries)	2089.9	17.2	12.4	Others (1949) (99.2% cities)	10076.6	83.0	83.1
$\sum^{d}$	119 countries	12135.0	100.0	100.0	1964 cities	12135.0	100.0	100.0

Key: P—Publications; C—Citations received.

[a] Includes Hong Kong and Macau.

[b] The high rank of Washington, D.C. (US) can be explained by the fact that most US agencies are headquartered there. It turns out that many authors affiliated with such agencies (e.g. USDA Forest Service) are actually located in other places (e.g. Delaware, OH), however, their location in Scopus was assigned to Washington, D.C. owing to the headquarters of the institution (e.g. see Peters *et al.* (2014)).

[c] State College, PA, location of the Pennsylvania State University (Penn State); see Robinson (2015) for an overview.

[d] 12 239 publications in Scopus were analysed, however, for 104 papers (0.8%) the affiliation was missing.

Table 5: Trends in the output of the top 10 players. The sparklines indicate the longitudinal trend of the sampled output for each country. The trend of the relative share is illustrated in Figure 5.

	Output [no. of papers]			Share [%]	
	2000	Trend	2014	2000	2014
United States	182.00		307.87	35.76	24.05
China	25.50		174.00	5.01	13.59
United Kingdom	90.53		67.78	17.79	5.30
Germany	18.20		83.50	3.58	6.52
Canada	25.00		61.08	4.91	4.77
Netherlands	19.50		46.67	3.83	3.65
Australia	15.83		48.50	3.11	3.79
Italy	7.20		42.00	1.41	3.28
Spain	5.50		56.17	1.08	4.39
France	11.50		36.28	2.26	2.83
Other countries	108.23		356.15	21.26	27.82
World[a]	509.00		1280.00	100.00	100.00

[a] The totals do not correspond to Table 1 because a small number of papers were not in Scopus or their affiliation was missing.

of several papers (Hayashino *et al.*, 2003; Rahman *et al.*, 2005; Shelton, 2008; Leydesdorff and Zhou, 2005; Basu, 2014; Zhou and Pan, 2015).

The results presented in this section also show that there are 76 countries¶ without a single paper in the observed sample.

Normalising the output: efficiency of nations

The so far presented results show the absolute output, but it might not be fair to compare the output of countries such as China and the United States with smaller and/or poorer countries which might be considered productive when certain circumstances are taken into account.

Measuring the efficiency of a country in the output of scientific papers with respect to econometric and demographic indicators such as the gross domestic product (GDP), R&D expenditure, and number of researchers has been a topic of a large number of research papers (May, 1997; King, 2004; Basu, 2014; Rousseau and Rousseau, 1998; Vinkler, 2008; Leydesdorff and Gauthier, 1996; Leydesdorff and Wagner, 2009; Shelton, 2008; Ugolini *et al.*, 2007; De Moya-Anegón and Herrero-Solana, 1999; Blickenstaff and Moravcsik, 1982; Man *et al.*, 2004; Falagas *et al.*, 2006; Amsden and Mourshed, 1997; Gul *et al.*, 2015). Such analyses help to understand the relation between the economic indicators and the volume of the innovative output for estimating a nations' scientific wealth, and for evaluating scientific policies (Crespi and Geuna, 2008; Pouris, 2012).

In this study the approaches found in the cited studies were used and applied to GIScience. Further, as with the previous section, the received citations will be analysed. An optimal proxy to standardise the national output would be the national R&D expenditure in GIScience or the number of GIScientists, however, no such data exists. Therefore this analysis relies on the GDP, as most other scientometric studies do.

For this analysis countries with less than 5 publications were filtered out to remove statistically insignificant and not representative cases.

Figure 6 reveals the relation between the GIScience output with respect to the population and GDP. Most of the top productive countries (Table 4) are in the band of a GDP of approx. US$40–50k per capita, yet the plot shows that their efficiency considerably varies in comparison to their size. Notable deviations are the modest cases of France and Japan, which might be explained by the fact that their scientists might be more inclined to publish in local (non-English-speaking) journals not covered in this study. This topic has been a subject of several research papers (Van Leeuwen *et al.*, 2001; Man *et al.*, 2004; Van Leeuwen *et al.*, 2000).

Figure 7 and Table 6 present the rank of top countries by the number of publications per GDP. The world average performance is 0.199 journal papers per US$B of GDP. This rank gives a more realistic view on the performance of countries given their economic power. The Netherlands ranks first in GIScience efficiency, similarly as in other disciplines (Rousseau and Rousseau, 1998). A strong correlation is observed between the national output and the national GDP (0.94),

¶There are 195 United Nations (UN) member states (193) and non-member permanent observer states (2) as of the submission of this paper (July 2015). This figure is taken as the authoritative number of sovereign states.

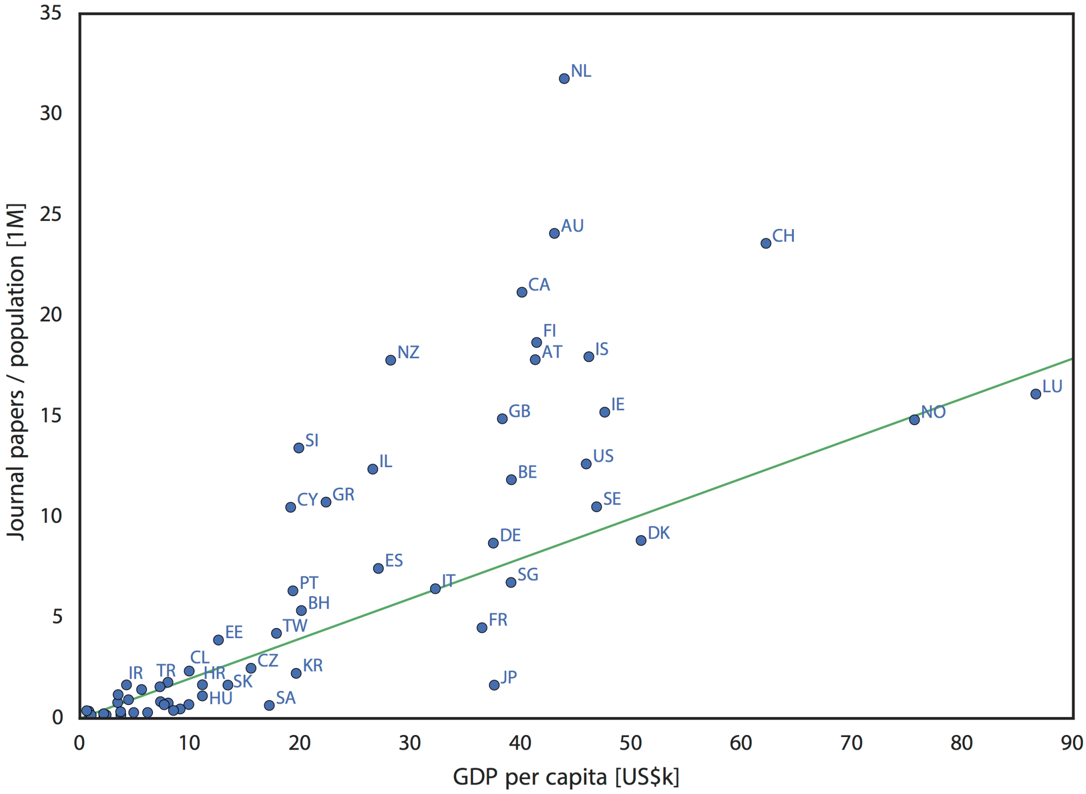


Figure 6: Relation between a nation's economic and GIScience wealth. The green line represents the average performance (0.2 papers/US$1B of GDP). Pronounced countries are labelled according to ISO 3166. The GDP and population represent the mean of the period 2000–2014. Source of the economic and demographic data: World Development Indicators, World Bank (2015).

Table 6: Top countries by output efficiency[a]. The values in brackets indicate the rank in relative impact, based on the RCI[b].

Output efficiency			
	Country	Eff.[a]	
1.	Netherlands	0.724	(11)
2.	Slovenia	0.677	(16)
3.	New Zealand	0.632	(44)
4.	Zimbabwe	0.623	(61)
5.	Australia	0.560	(20)
6.	Cyprus	0.549	(57)
7.	Canada	0.529	(7)
8.	Greece	0.482	(24)
9.	Israel	0.467	(18)
10.	Finland	0.451	(47)
11.	Kenya	0.433	(40)
12.	Austria	0.432	(3)
13.	Iran	0.394	(48)
14.	Iceland	0.390	(41)
15.	United Kingdom	0.389	(12)
	World average	0.199	

[a] Efficiency: number of papers divided by GDP [US$B].
[b] Share of citations divided by the share of publications in the sample.

which is higher than in other related studies: 0.69 (De Moya-Anegón and Herrero-Solana, 1999), 0.45 (Vinkler, 2008).

Worldwide distribution of citations

A question that follows is: are countries productive in GIScience also comparatively successful in attaining citations? Therefore the citation share and output share have been compared. Table 4 shows that there is a difference between the two, which also affects the rank, e.g. France comes ahead of Spain when accumulation of citations is considered.

Some countries produce papers that on average have a higher impact than others, however, these discrepancies could also be (at least partially) explained by the fact that topic-wise the compo-

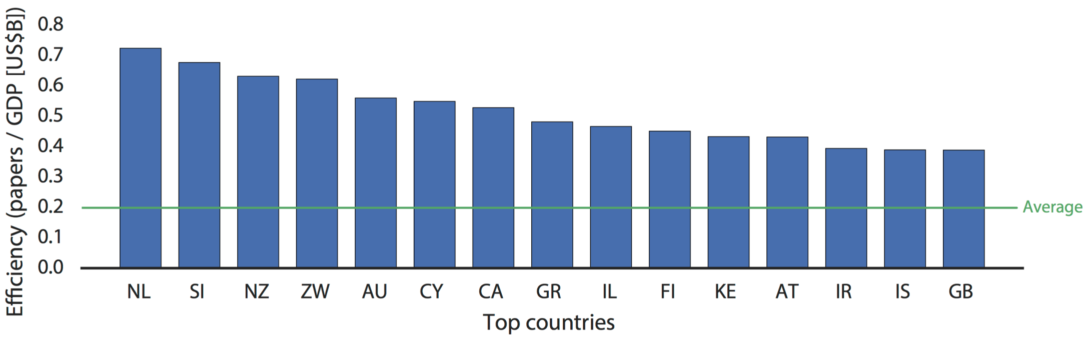


Figure 7: Most efficient countries, based on the number of journal papers divided by GDP.

sition of papers might not be equal among countries: some topics, more popular than in other countries, tend to gain more attention than others. A notable difference exists in the case of China. As seen in Figure 2, China's historical output is not homogenous, therefore, its increased publication rate possibly did not yet start to accumulate citations, as that normally follows with a delay.

In relative terms, the impact of a country can be assessed with the relative citation impact (RCI), the ratio between the share of citations and share of publications (May, 1997). A different view on the performance has been obtained, and Table 6 additionally shows the RCI ranking of the most output-efficient countries. However, ranking countries by RCI is avoided since the results suggest that in small samples a co-authorship in just one highly cited paper may substantially boost a country's rank.

Are countries efficient in output also efficient in citedness? No, there is a zero correlation (0.016), and as visible from the Table 6 there is a discrepancy between the efficiency and RCI rankings (although there are cases whose rank is consistent).

4.5 Collaboration

Measuring the international scientific collaboration is important to understand the international network of science and collaborative centres (Luukkonen *et al.*, 1993; Katz and Martin, 1997). A paper is considered international if more than one country is indicated in the affiliation (Schubert and Braun, 1990).

The affiliations stated in the surveyed publications have been analysed: 22.7% publications in the sample are result of an international collaboration (recently this increased to almost a third; see Tab. 1). Figure 8 shows that the share of international papers is growing, which is consistent with other disciplines. However, the share of international collaboration in 2000 (10.0%) was

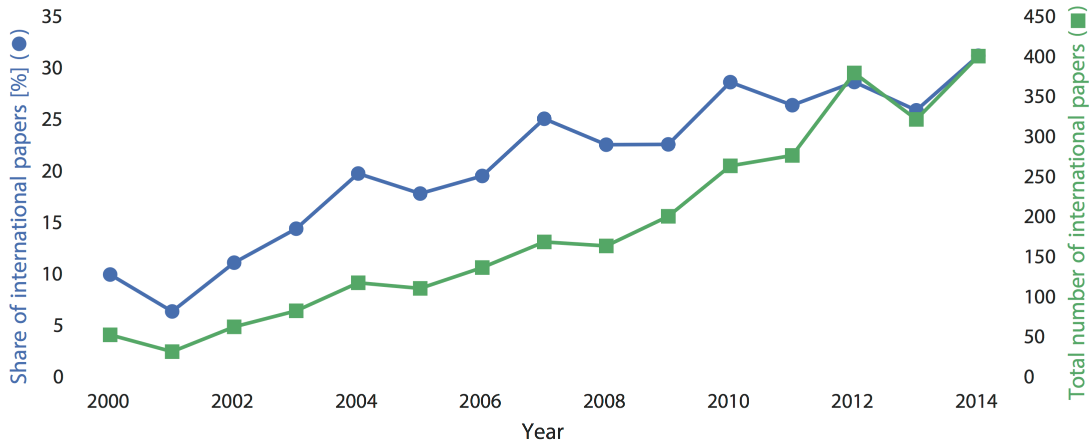


Figure 8: Temporal trend of the international collaboration in GIScience.

significantly lower than the worldwide share in a cross-disciplinary study (15.6%) (Wagner and Leydesdorff, 2005).

Table 7 provides the data on the most frequent pairs collaborating in GIScience, both on national and city level. Most collaborations belong to the pair of China and the US, which is also the case in many other disciplines (He, 2009).

The quantity of collaboration by country roughly corresponds with content of the Table 4. However, in relative terms, another ranking is exposed: Romania is the most collaborative country (92%; i.e. 12 out of 13 papers are international). It is followed by Luxembourg (88%), Indonesia (85%), Pakistan (84%), Morocco (78%), Kenya (75%), Colombia (73%), Egypt (71%), Hungary (68%), Algeria (67%), Denmark (64%), Croatia (64%), Iceland (63%), Czech Republic (61%), and Belgium (60%).

While international collaboration in GIScience is frequent, papers originating from more than a few countries are uncommon. The record is set by the paper of Hjelmager *et al.* (2008) with authors from 13 countries.

Studies have been carried out to find the relation between collaborative papers and citation impact, however, only at a publication level (Leimu and Koricheva, 2005b; van Raan, 1998; Figg *et al.*, 2006). Relating these findings to the previous section, Figure 9 shows the relation between the RCI and *collaborativeness*. A modest correlation of 0.166 has been found, indicating that countries open to collaboration do not have significantly more impact. At a publication level, a zero correlation (0.036) was found between the number of participating countries and the attained citations, demonstrating that in general having more collaborating countries in a paper does not result in a higher impact.

Table 7: Top 15 country-to-country and city-to-city collaborations, ranked by the number of papers published together.

Country pair[a]		*f*	City pair[a]		*f*
China	United States	333	Beijing	Wuhan	110
Canada	United States	126	Beijing	Nanjing	53
United Kingdom	United States	103	Beijing	Hong Kong	50
Canada	China	89	Hong Kong	Wuhan	47
Germany	United States	82	Enschede	Wageningen	44
Australia	United States	63	Beijing	College Park	35
Netherlands	United States	57	Beijing	Berkeley	32
China	Netherlands	54	Enschede	Wuhan	30
Italy	United States	49	Beijing	Guangzhou	26
Germany	Netherlands	48	Toronto	Wuhan	25
South Korea	United States	46	Delft	Enschede	23
Germany	United Kingdom	45	Beijing	Chengdu	22
Germany	Switzerland	44	Fairfax	Wuhan	21
Australia	United Kingdom	39	Beijing	Hangzhou	20
China	United Kingdom	38	Beijing	Madison	20

Key: *f*—Frequency of collaboration (number of joint papers).
[a] Alphabetic sort of the elements in each pair.

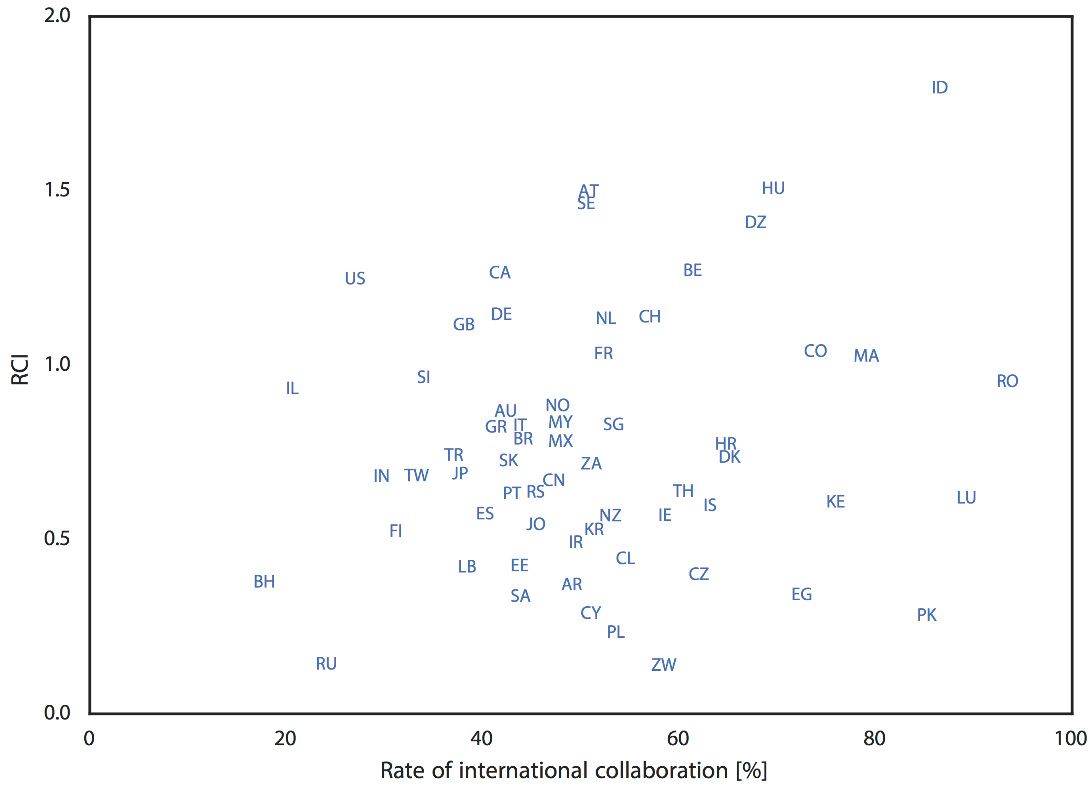
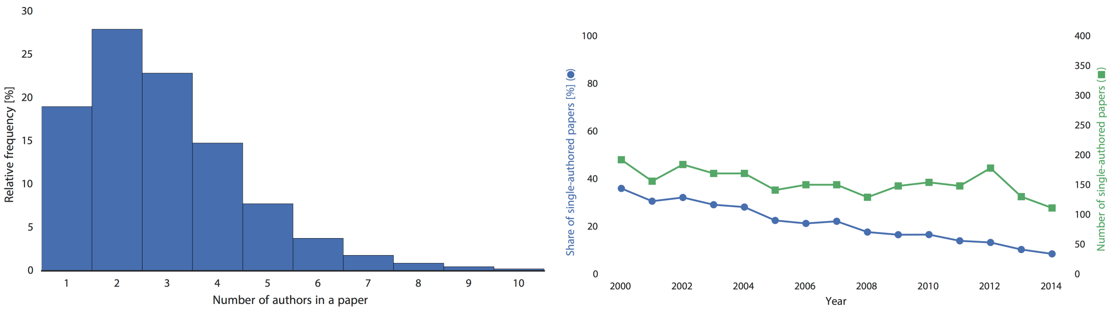


Figure 9: Relation between the rate of international collaboration and the nation's GIScience relative impact.



(a) (b)

Figure 10: Dissecting the authorships: (a) distribution of the number of authors of a paper; and (b) the relative and absolute number of papers signed by a single author.

4.6 Authorship

Using the metadata of authors of publications, an analysis of authorship was made. Results indicate a high fragmentation between the authors of papers in the observed sample: there are 22,252 authors, with an average of 1.6 papers per author. Furthermore, 75.5% authors have published one paper in the sample, and 1.2% authors have published 10 or more papers.

Figure 10 indicates the distribution of authors per paper (the average number of authors per paper is 2.96), and that single-authored papers are falling out of fashion: in the observed period, the rate of papers authored by one person dropped significantly (from 36.2 to 8.7%). This trend is consistent with other disciplines (Huang, 2015).

The data on the authorship was coupled with the data of citations. Researchers suggest that the quantity of citations received per author might not be consistent with the number of published papers (Waltman *et al.*, 2013), hence in order to investigate the GIScience trend, it was studied whether papers of seasoned GIScientists have a higher relative impact. The results suggest that not, as there is zero correlation between the number of papers published by an author and the citedness of her/his papers. This goes together with the interesting observation that some of the authors of the most cited papers (Table 3) have not published any other paper in the observed journals in the considered time period. In fact, these results are consistent with other disciplines such as chemical engineering (Peters and van Raan, 1994).

Another aspect that was investigated is the relation between the number of authors in a paper and the received citations. It has been suggested by some researchers that the number of authors increase the number of citations (Glänzel and Thijs, 2004a; Leimu and Koricheva, 2005a; Vieira and Gomes, 2010). However, the correlation between the number of authors and the NCII was found to be very weak (0.069).

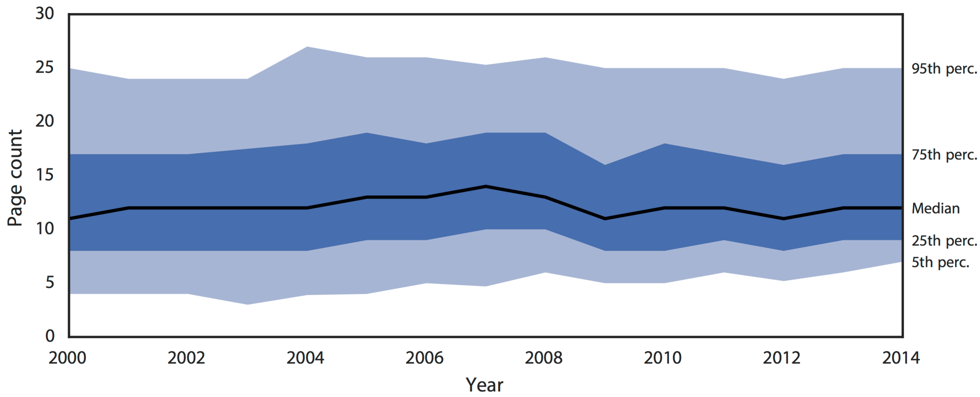


Figure 11: Length of papers through time, with the indicated dispersion (percentiles).

Finally, unlike in some other disciplines, there are not many papers with more than a few authors (see Figure 10). The paper with most authors (26) in the sample is the one of Albertz *et al.* (2005).

4.7 Page count

Since the metadata of papers contain their number of pages, the length of papers was analysed as well. It was found that the average length of a paper in the analysed sample is 13.4, and that it seems to have been stable during the past 15 years (Figure 11). The plot also suggests that papers longer than 25 pages are not frequent.

It has been suggested by scientometric researchers that lenghtier papers attract more citations (Falagas *et al.*, 2013; Peters and van Raan, 1994; Vieira and Gomes, 2010). However, it turns out that in GIScience there is almost no correlation between the page count and NCII (r = 0.053, n = 12217; and r = 0.070 when using the unadjusted citation count). It is interesting to note that this is not the case in many other disciplines, e.g. 0.70—medicine (Falagas *et al.*, 2013).

5 Altmetrics

Altmetrics (short for alternative metrics) are being increasingly used as an alternative to traditional indicators such as the impact factor or citation count (Haustein *et al.*, 2014b; Piwowar, 2013). They include different measures of an impact of a publication, mostly related to social media activity around a scholarly article. Examples are mentions on Twitter and citations in Wikipedia articles. Considering that they indicate the societal impact, altmetrics can complement citations when assessing the impact of a publication (Haustein *et al.*, 2015b).

Herein it is investigated how GIScience stands with respect to altmetrics, and whether there is a relationships between traditional metrics and altmetrics. Furthermore, this is interesting to investigate since there are differences between disciplines when taking into account social media (Holmberg and Thelwall, 2014; Ortega and Gorman, 2015). Social media has already been a topic of papers published in this journal, and it is rapidly gaining importance in GIScience research (Sui and Goodchild, 2011; Bakillah *et al.*, 2015; Yin and Shaw, 2015; De Albuquerque *et al.*, 2015; Huang and Xiao, 2015; Huang and Wong, 2015; Longley and Adnan, 2016; Steiger *et al.*, 2015b,a; Jongman *et al.*, 2015).

In the continuation two sources of altmetrics are analysed: Altmetric and Mendeley.

5.1 Altmetric

Altmetric captures mentions of publications in non-academic sources, such as news, policy documents, mentions on Twitter, blog posts, Wikipedia, Facebook posts, Google+ posts, and LinkedIn (Adie and Roe, 2013). It assigns a single numerical score to each paper, an indication of attention surrounding a research paper. The score is assigned according to a weighted algorithm based on three factors: (i) volume of the mentions (how many?), (ii) source of the mentions (i.e. it differs between high-profile news stories, re-tweets, and Wikipedia references), and (iii) author of the mentions (e.g. a journal publisher, or an influential academic) (Davies, 2015). While the Altmetric score embeds tweets, Twitter is gaining more and more importance as a medium of academic communication (Shuai *et al.*, 2012), hence it is considered separately in this section.

Altmetric started to operate in 2010, hence only papers published as of 2011 are taken into account. According to the analysis 20.7% of analysed GIScience papers have been mentioned on Twitter at least once. This value puts GIScience slightly below the average of 21.5% (Haustein *et al.*, 2015b,a).

Furthermore, the analysis has shown that there is a trivial correlation between the citations and mentions on social media (i.e. Altmetric score 0.145, and Twitter—0.144), similar to the conclusions found in related work (Haustein *et al.*, 2014a). This indicates that mentions do not guarantee increased citedness, but it also reinforces the idea that altmetrics should be considered as complement and perpendicular indicator to the traditional metrics.

As of writing this manuscript, the publication with the highest Altmetric score is the one of Yoshimura *et al.* (2014): "An analysis of visitors' behavior in The Louvre Museum: a study using Bluetooth data" published in EPB (25.85 score, and 9 tweets). The publication most mentioned on Twitter is the paper of Steiniger and Hunter (2013): "The 2012 free and open source GIS software map — A guide to facilitate research, development, and adoption" published in CEUS (Altmetric score of 22.45, and tweeted 28 times). These values are not particularly high in comparison to other disciplines, for instance, the recent paper of Blake *et al.* (2015), one of the highest scoring papers in psychology, currently has a score of 346. This indicates that GIScience papers are not popular in sources covered by Altmetric, and that they might have a limited reach to the public comparing to larger disciplines.

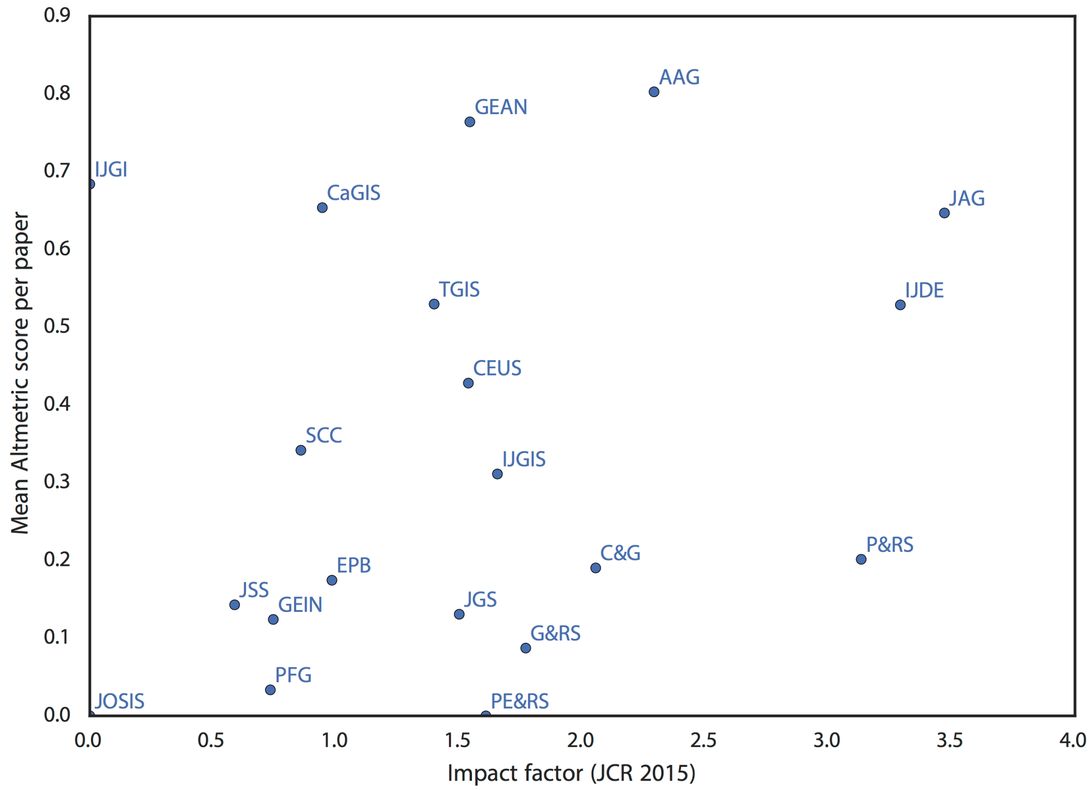


Figure 12: Relationship between the Altmetric score and the traditional impact of a journal. IF source: 2015 Journal Citation Reports (Thomson Reuters, 2015).

Although such metrics are positioned at an article level, it is interesting to analyse the altmetric impact of journals, and whether a high traditional impact of a journal implies a high impact in social media. Figure 12 shows the relation between the impact factor of a journal and the mean Altmetric score assigned to a paper in that journal in the period 2011–2014. The scatter plot illustrates a weak relationship ($r = 0.274$), and that there is a substantial difference between journals when taking into account the presence in social media.

5.2 Mendeley

Mendeley is the Elsevier's software for managing and sharing research papers. It is valuable for scientometric analyses since their API provides statistics such as the count of people that have a paper in their library. Mendeley data have been used in a number of research papers for various analyses (Mohammadi *et al.*, 2015b; Mohammadi and Thelwall, 2014; Zaugg *et al.*, 2011; Li and Thelwall, 2012; Haustein *et al.*, 2014a; Thelwall and Maflahi, 2015; Bar-Ilan *et al.*, 2012; Bornmann and Haunschild, 2015; Fairclough and Thelwall, 2015).

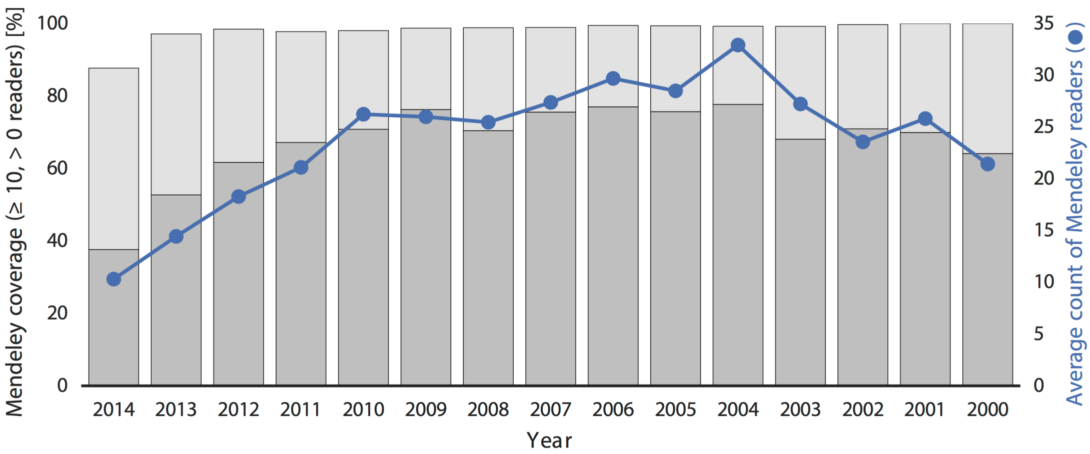


Figure 13: Mendeley readership statistics by year of publication. Note that the x-axis is inverted to indicate ageing.

For each paper in the sample that has a DOI, information about the number of readers has been retrieved in order to understand the prevalence of GIScience papers and trends among researchers with respect to some of the previously investigated metrics.

It was found that 97.2% of GIScience papers covered by this study have been bookmarked by at least one reader in Mendeley, and that there are 21.8 readers per paper. This rate of attention is significantly better than any other discipline (with an average of 66.2%) (Haustein *et al.*, 2014b,a; Mohammadi *et al.*, 2015a). In the research of Haustein *et al.* (2014a) psychology ranks as the first discipline with 81.0% papers being included in Mendeley libraries, and GIScience ranks substantially better than that.

When setting a threshold to 10 readers, to highlight papers that have a wider audience, the analysis shows that 64.4% papers have at least 10 readers. The list of top bookmarked papers mostly corresponds to the list of top cited papers (Table 3). The most bookmarked publication is also the most cited one, currently with 962 readers.

Figure 13 depicts these indicators by the year of publication. It shows that papers are imported into Mendeley libraries with a delay, and that older papers virtually reach a perfect coverage. This might indicate that readers do not become aware of papers immediately and/or that papers need time to generate interest. The plot also illustrates the average readership per paper published in a year. It shows a drop in interest in papers older than ten years. This is congruent with the obsolescence of citations (Figure 3).

Another important aspect is the relationship between citations and the readership population, which is shown in Figure 14. The correlation between NCII and reader count is 0.772 (the correlation between citations and readership is 0.719). This is a stronger relation than most disci-

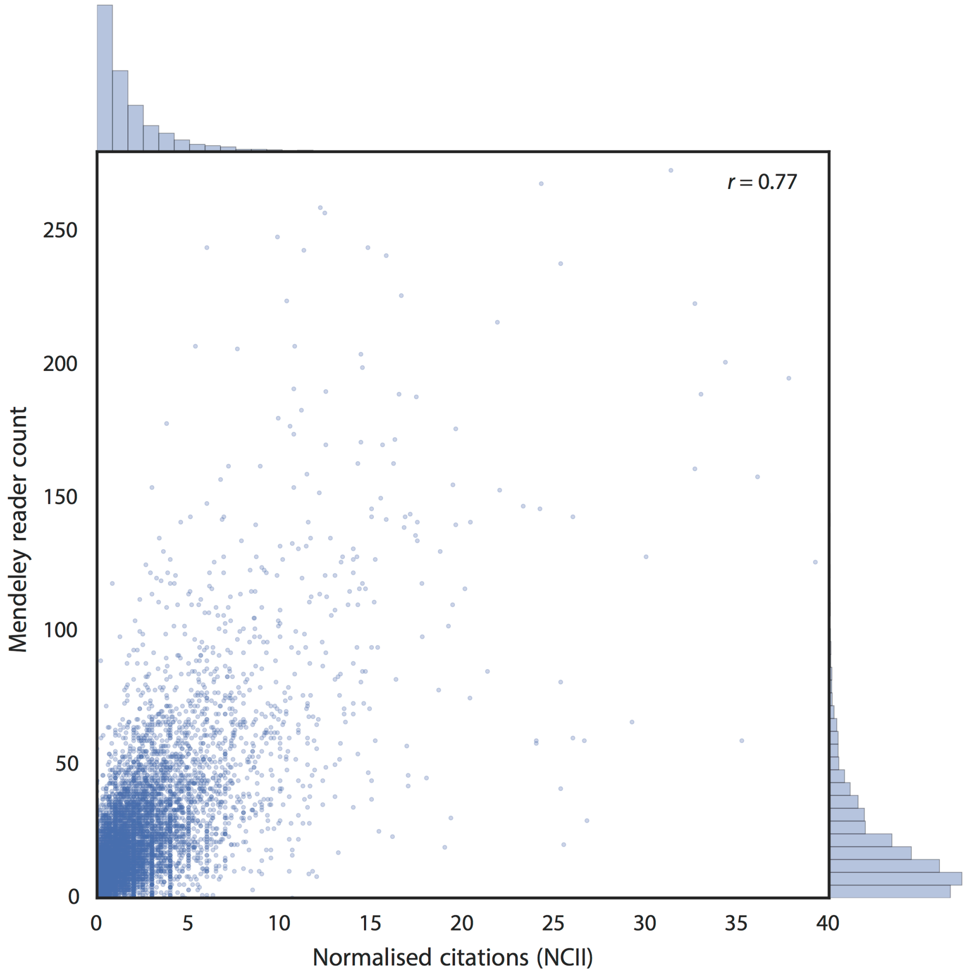


Figure 14: Mendeley readership volume correlates with citations.

plines (0.677) (Haustein *et al.*, 2014a,b), especially when considering humanities (0.428) (Mohammadi and Thelwall, 2014), and it is similar with genomics and genetics (0.778) (Li and Thelwall, 2012).

6 Conclusions

This scientometric work analysed 12436 papers published in several GIScience journals in the past 15 years. Thanks to the availability of data and their retrieval through APIs, it was possible to analyse several aspects to understand a number of trends in GIScience.

For instance, besides the discussed results, it was found that top 20% cited papers account for 73% citations, there is a weak correlation between a nation's output and its population (0.329), 14.9% papers published in 2000–2014 are yet to be cited, and that there are large differences in the citations of the papers of the same researcher.

Some of the indicators presented in this paper have not been previously used, e.g. the Mendeley relation to the NCII, potentially presenting a contribution in the contemporary field of altmetrics. In most cases, GIScience exhibits behaviour consistent with other disciplines, however, it should be noted that GIScience stands out as a leading discipline in regards to the presence among Mendeley users.

This work, as it is the case with similar analyses, is not without limitations. First, the presented delineation of selected outlets does not capture the whole GIScience literature, hence it cannot be considered to study the complete GIScience landscape and the global GIScience output. Second, the selection of relevant GIScience journals is subject to some bias and subjectivity, and a different selection of outlets would likely to an extent influence the outcome of some aspects of this analysis. However, this is inevitable, and the large sample of journals and papers used in this study is sufficiently diverse to capture the trends and to alleviate the bias. Third, the analysed sample contains a number of not exactly GIScience papers. For instance, this is reflected in the domination of remote sensing topics (see the top papers in Table 3). As much as GIScientists publish in other venues, the considered set of journals includes non-GIScience papers. A strict filtering would not be possible without substantial additional work and/or involving advanced text mining techniques, but also without a clear definition what is exactly a GIScience paper. I am afraid that considerable additional work is required to carry out an analysis that would efficiently delineate GIScience literature in a more precise manner and without compromises due to fuzzy boundaries of the discipline and mixed scopes of outlets, but also due to the lack of a firm consensus among GIScientists on these topics. However, all these limitations are consistent with scientometric studies that focus on disciplines.

For future work it would be interesting to revisit this topic in 5 or 10 years, and analyse what has changed since this study has been carried out. With the increasing availability of publication metadata, and the rising prominence of altmetrics, possibilities for future work are ceaseless.

Most importantly, it would be interesting to work into two specific directions. First, it would be beneficial to investigate trends of particular topics in GIScience. While it was not feasible to automatically classify papers according to finely defined sub-disciplines (e.g. data structures, geo-visualisation) lately some topics in GIScience seem to be gaining more interest than others, such as volunteered geoinformation (Kunze and Hecht, 2015; Arsanjani *et al.*, 2015; Ballatore and Mooney, 2015) and 3D geoinformation (Arroyo Ohori *et al.*, 2015; Donkers *et al.*, 2015). Furthermore, a relation between more traditional and relatively new topics appears to emerge, for instance, spatial data quality and uncertainty analyses applied to volunteered geoinformation and 3D geoinformation (Camboim *et al.*, 2015; Fan *et al.*, 2014; Biljecki *et al.*, 2015). Second, continuing the analysis of the national aspect provides fertile ground for further research opportunities. This paper has shown that there are substantial differences between countries in consideration of their output and received citations. For instance, US accounts for 31.3% of the analysed GIScience output, approximately as much as 111 countries (if we also consider the remaining 76 countries with 0 papers, that amounts to 187 countries). After adjusting the data according to a nation's wealth to derive the efficiency, another ranking is exposed where the US ranks 22nd. Such analysis benchmarks a nation's output and efficiency, thus its extension would be valuable as an input in scientific policies that would help to improve GIScience output, and could be related to the research on the economic value of geoinformation (Castelein *et al.*, 2010; Bernknopf and Shapiro, 2015; Trapp *et al.*, 2015).

Acknowledgments

I gratefully acknowledge the excellent comments and valuable suggestions of the three anonymous reviewers and editor Prof Robert Weibel, which have improved the quality of the manuscript.

This analysis would not be possible without data from Scopus, Altmetric, Mendeley, and the World Bank. These sources are much appreciated. In addition, I am thankful to Meshna Koren from Elsevier for promptly answering my queries about Scopus.

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