The utility of Google Scholar when searching geographical literature: comparison with three commercial bibliographic databases

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Abstract

This study aims to highlight what benefits, if any, Google Scholar (GS) has for academic literature searches in the field of geography, compared to three commercial bibliographic databases: Web of Science (WoS) and FRANCIS (multidisciplinary databases) and GeoRef (specialized in geosciences). To ensure a valid comparison, identical bibliographic searches were applied using each of the four bibliographic tools. To exclude automatic variations of the ten keywords tested, they were placed between quotation marks and searched only in the "title" field of the respective search tools' interfaces. The results were limited to bibliographic references published from 2005 to 2009. In order to assess the repeatability of the results, the exact same process was repeated monthly between November 2010 and July 2011. Initially the whole set of results was analyzed, after which the search results for two keywords (selected since they yielded a manageable number of results) were studied in more detail. The results indicate that GS search results show a large degree of overlap with those of the other databases but, moreover, yield numerous unique hits, which should be useful to researchers in both the fields of human and physical geography. GS leads the other tools widely on number of results, independently of keyword, subfield, year of publication, or time of search.

Keywords: bibliographic database analysis, geographical literature, Google Scholar, Web of Science; FRANCIS; GeoRef

Introduction

Analysis of bibliographic tools (BTs) is a growing academic research field nowadays, particularly comparison between traditional commercial databases (DBs) and free web search engines, such as the well-known Google Scholar (GS), launched in 2004.

Studies have employed several search criteria to evaluate BT performance, including citations (Bar-Ilan 2006; Mingers and Lipitakis 2010; Bauer and Bakkalbasi 2005), keywords (Gardner and Eng 2005; Robinson and Wusteman 2007; Falagas *et al.* 2008; Notess 2005), and author names (Mikki 2010; Bar-Ilan *et al.* 2007). The elements compared in search results have included citation display, bibliographic tool coverage, result overlap, and h-index values (Bar-Ilan 2008; Neuhaus *et al.* 2006; Walters 2007; 2011).

The fact that GS provides a large number of results has already been discussed in relation to several scientific domains, including medicine, biology, life and environmental sciences, and engineering (Lohonen *et al.* 2010; Neuhaus *et al.* 2006; Meier and Conkling 2008; Jones 2005). However, at the present time, few existing analysis relate specifically to physical geography, and practically none to human geography. Thus, *GS's coverage of geography is still to be ascertained.*

Across fields, early studies show that despite a high number of results obtained, GS has not performed optimally with regard to update frequency, precision of information, or accuracy of the number of citations (Gardner and Eng 2005; Notess 2005). However, later studies rank GS among the top bibliographic tools in terms of precision, relative recall, and ability to retrieve "Top Ranked Pages" (Robinson and Wusteman 2007; Walters 2007; 2011). Meier and Conkling (2008) and Cusker (2013) state that GS is a good option for engineers, and Mikki (2010) argues that it should be included in library programs for information literacy instruction. Further, Chen (2010a) shows that GS has become an important tool in bibliographic research and emphasizes the declining value of commercial DBs.

Overall, the evaluation of GS appears to have improved with time. The progressive acceptance of "Google Search Mode" for bibliographic search by the scholarly world could in part explain this progression, as could the gradual improvement of GS's coverage. In fact, in 2010, Chen (2010b) repeated the earlier experimentation of Neuhaus *et al.* (2006) on seven selected DBs and indicated a "dramatic improvement" of GS's coverage since the earlier study. Since GS collaborates with several scientific editors, and their contract length is not known, GS's coverage could be much more variable over time than that of traditional DBs. *This condition has to be considered when using GS.*

Going farther into the matter of the coverage of GS as opposed to other bibliographic tools, the previously mentioned Neuhaus *et al.* (2006) compared a set of 47 bibliographic DBs with GS and discovered that each of them was partially or fully covered by GS (between 6% and 100%). Upload frequency and publication date and publication language bias were checked. "Mean scores of Google Scholar database coverage for all databases assigned to a particular discipline category were calculated" Neuhaus *et al.* (2006). The mean discipline category scores are high for science and medicine (76%), low for the social sciences and education (39% and 41% respectively), and very low for humanities (10%). The mean score for the multidisciplinary DBs category is 77%, while for discipline-specific DBs, GS's coverage decreased dramatically to only 26% of GeoRef. Chen (2010b) who repeated this experiment, didn't consider GeoRef; however, Musser (2008) found that the overlap between GS and GeoRef was 55%.

Another study targeting GeoRef was performed by Brown (2009). This study primarily compared GeoRef and GS content with that of randomly selected bibliographies from graduate student theses and dissertations. For searches of the geosciences literature, Brown (2009) recommended the use of these tools in the following order: Scopus and/or Web of Science, Google Scholar, GeoRef, WorldCat, and Google Books. Mikki (2010) compared WoS with GS for earth sciences (specifically, she searched the papers of 29 authors working on climate and petroleum geology issues) and found a high similarity of values for the two sources. Recall of WoS documents by GS was 85%, and "the number of search results and their citations was higher in GS."

In this study, through an investigation of how GS performs in the field of geography, we intended to make some important additions to the existing knowledge on GS. We also wish to determine how the tool's performance in a given field evolves over time: to our knowledge, this is the first study to tackle bibliographic search tools evolution over time.

Aim and Objectives

The aim of this study was to assess the current performance of the GS search engine in the subfields of physical and human geography. To do so, we relied on the search tools currently used in the field as comparison cases: the discipline-specific GeoRef for the scientific discipline of physical geography, and the American and European multidisciplinary databases Web of Science (WoS) and FRANCIS. FRANCIS suits particularly for the social science of human geography although it covers some papers in physical geography too.

Among several established methods, we chose to perform the study by successively searching ten selected keywords (search criteria) using each of the four bibliographic tools. Despite the laborious nature of the processing of results, this approach has the advantage of familiarity with the scholarly researcher's usual search process for bibliographic references. The searches covered several publication years (2005–2009) and were repeated several times to ensure quality of results.

We compared the GS results to those of the commercial DBs and, to allow a more nuanced interpretation, we compared traditional DB results among themselves too.

For each of the ten keywords, we first conducted statistical analysis of the results in order to identify significant variations and to allow the derivation of interpretations. For two of the ten keywords, we then conducted a more detailed comparison of results, eliminating the noise, making allowances for overlap and unique references retrieved by each of the four tools, and determining the different types of unique documents.

Our objective was to answer the following questions:

1) In the field of Geography, does GS give many more hits than the commercial bibliographic DBs GeoRef, WoS, and FRANCIS?
2) Are GS results very noisy because of duplicates or non-geographical references?
3) To what extent do GS results overlap traditional DB results?
4) Are the references found uniquely in GS to be considered reliable sources?
5) Are results and their implications different for the four bibliographic tools across human and physical geography subfields?
6) Are the results reproducible when the search process is repeated over time?

Methods

Bibliographic tools

Google Scholar is a freely accessible web search engine that indexes the full text of scholarly literature across a wide variety of publishing formats and disciplines. The exact years of coverage are not provided by Google, since they are in principle unlimited. Based on automatic reference recognition and through agreements with its partners, it provides access to articles, theses, books and abstracts from academic publishers, professional societies, online repositories, universities, and other websites.

Web of Science is a multidisciplinary citation database from Thomson Reuters that provides current and retrospective coverage in the sciences from 1900 to the present day. It covers 12,000 academic journals, including open access journals, and over 150,000 conference proceedings.

GeoRef is a DB specializing in the geosciences. Established by the American Geosciences Institute (AGI) in 1966, it contains 3.4 million references from 3500 journals (relating to the geology of North America since 1699 and the rest of the world since 1933). It provides access to journal articles, books, maps, conference papers, reports, and theses, including those in languages other than English, with 80,000 references added annually.

FRANCIS is a multilingual and multidisciplinary DB produced by INIST–CNRS (Institut de l'information scientifique et technique–Centre national de la recherche scientifique/Institute of Scientific and Technical Information–National Centre for Scientific Research), France, which mainly covers French and European literature in the humanities and the social sciences and contains 2.5 million records. A total of 8% of the literature in this DB is geographical literature, including books, conference proceedings, dissertations, journal articles, and reports from 2300 publications dating back to 1972.

The homepages of WoS,[1] FRANCIS,[2] and GeoRef[3] were used to perform the bibliographic searches. For GS, we used the advanced research interface on the *googlescholar.com* webpage.

Bibliographic search

To decide which keywords to consider, we carried out some tests using simple keywords and also multiple-word (composite) search terms in all the mentioned bibliographic search tools. In all cases, GS provided the highest number of results.

Composite keywords, being too specific, yielded low numbers of results that would not allow a comparative analysis. Therefore, we discarded them as inappropriate.

We selected ten simple keywords corresponding to broad concepts generally studied in geographical scholarship. These keywords are associated with scientific topics in geography, and most of them are currently used in different Departments at the University of Liège (namely, the departments of Geography and ArGEnCo—Architecture, Géologie, Environnement & Constructions/Architecture, Geology, Environment & Construction) and around the world. During our tests, we noticed that the keywords we chose are often mentioned in the keyword lists of scientific research papers published in earth science and geography journals (e.g., *Earth Surface Processes and Landforms*, *Catena*, *Geografiska Annaler Series A: Physical Geography*, *Geomorphology*, *Applied Geography*, *Area*, *Urban Studies*, *Geoforum*).

The keywords finally selected were:

- *urbanization, immigration, transportation, tourism, gentrification* (for human geography)
- *sedimentation, erosion, earthquake, tsunami, flood* (for physical geography)

To obtain comparable results from each of the bibliographic tools, it was essential to execute searches that were strictly the same for each tool. The keywords were placed between quotation marks, so that automatic variations of the searched keyword, imposed by the operating systems of the bibliographic tools, were excluded (e.g., sediment, sedimentary, sedimentous). The keywords were searched exclusively in the "title" field of the search interfaces, so that results would not be distorted by

[1] http://apps.webofkowledge.com/WOS_GeneralSearch.
[2] http://search.proquest.com/francis/advanced.
[3]http://web.ebscohost.com/ehost/search/advanced(georef).

the indexing characteristic of each BT. The bibliographic searches were carried out for the years 2005 to 2009: results are efficiently limited by publication year.

In order to find out more about the number of repeatable results, the identical overall process was carried out eight times, monthly, from November 2010 to July 2011 (one observation per month, with a single observation for May–June).

For the treatment of results, we used the reference manager software Zotero and EndNote as well as the spreadsheet application Excel.

Analysis of the number of results

The number of hits are represented statistically as the response variable, allowing the observation of any variation according to search characteristics (namely, selected keyword or set of keywords representing either physical geography or human geography, year of publication, database) corresponding statistically to the explanatory variables. In addition, studying the possible time dependence between the repeated counts was a second important objective of this analysis.

In order to gain some insight regarding dependences or interactions, so-called interaction plots have been created using R software. These plots display conditional averages of the number of results for all possible interactions between two explanatory variables (i.e., the variables database and selected keywords yield 4 x 10 interaction terms). Plotting these conditional averages in an organized way (that is, by using line segments joining them) enabled us to visualize any constant behavior of the response variable across the categories of explanatory variables or, on the contrary, any dependence between them. This is an exploratory tool, often advocated as a preliminary step before the definition of a model.

Reference analysis—a case study

As several of the bibliographic tools analyzed are multidisciplinary, results related to scientific fields other than geography are likely to be yielded when performing searches with the selected keywords. This is a major disadvantage of using keywords as search criteria. It is well known that GS displays a lot of duplicate references; as our analysis required correct lists of unique references exclusively in the field of geography, we had to manually select the results.

Because this selection process took a long time, we worked with two keywords only for this phase: "urbanization" for human geography and "sedimentation" for physical geography. In fact, the other keywords could not be considered anyway, since they provided more than 1000 results per year in GS, which displays only the first one thousand (with the exception of "gentrification," which yielded too low a number of results for the analysis).

This specific task, requiring both geographical and librarian skills, was completed by the first author, a geographer working as a geosciences librarian. To select for geographical literature across all the bibliographic tools, including WoS, she relied to the "Research Areas" classification of WoS. The reference manager EndNote was used for selection of the geographical references and also to remove duplicates for GS.

For the two selected keywords ("urbanization" and "sedimentation"), the percentages of references from each BT that were geographical references were calculated.

Overlap and specificity

Traditional overlap (TO) and *relative overlap* (RO) were calculated for each pair of BTs, on the basis of the sets of geographical references that were retrieved for the two selected keywords over the five-year target period (2005–2009) and manually selected. *Traditional overlap (TO)* is defined as follows (Gluck 1990; Hood and Wilson 2003; Bar-Ilan *et al.* 2007):

$$\% \, TO = 100 \times \frac{|\mathrm{PUBL}\, A \cap \mathrm{PUBL}\, B|}{|\mathrm{PUBL}\, A \cup \mathrm{PUBL}\, B|}$$

where PUBL *X* is the set of publications retrieved from database *X* (Bar-Ilan *et al.* 2007)

Relative overlap (*RO*) is defined as:

$$\% \, RO \text{ in A} = 100 \times \frac{|\mathrm{PUBL\,A} \cap \mathrm{PUBL\,B}|}{\mathrm{PUBL}\, A} \quad \text{and}$$

$$\% \, RO \text{ in B} = 100 \times \frac{|\mathrm{PUBL}\, A \cap \mathrm{PUBL}\, B|}{\mathrm{PUBL}\, B}$$

Both TO and RO are 100% if the sets of publications from DBs A and B are equal; if they are completely different, then both TO and RO are equal to 0%. RO is a more developed measure, expressing the two-way relative overlap of the secondary sources.

By using EndNote, we could identify specific references for each of the search tools used. We also determined the corresponding document types (journal articles, theses, reports, conference proceedings, unpublished works, patents, maps, and books or book chapters).

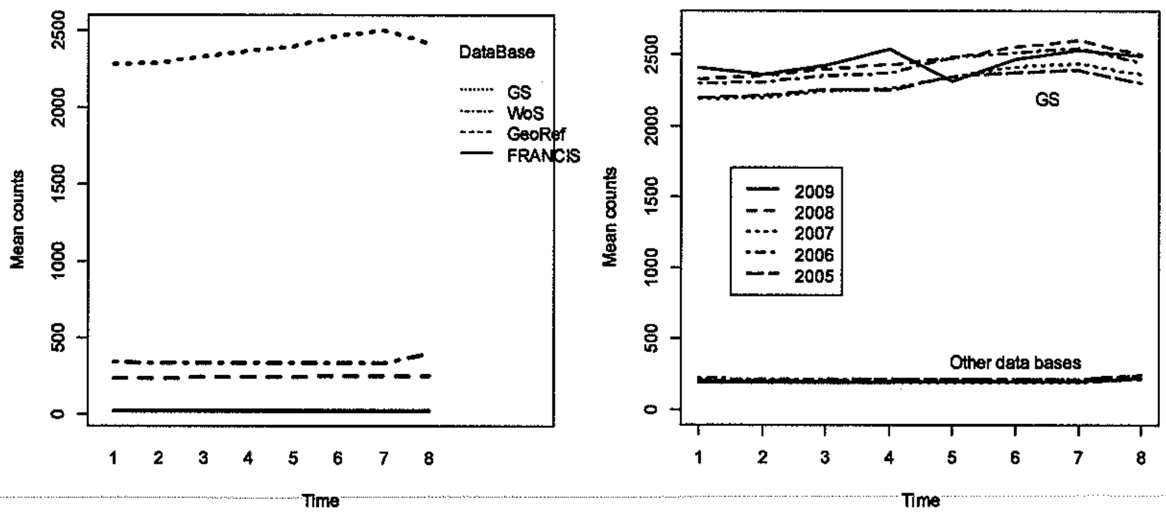
Results

Analysis of the number of results

Time evolution of search results

In order to determine whether the search results were repeatable or not, interaction plots were drawn up; they are represented in Figure 1. The left panel (Figure 1a) plots the average number of results conditioned by the dates of the search (classified as time categories 1 to 8 on the horizontal axis) and by the different BT. The right panel (Figure 1b) illustrates the average number of results using the dates and the reference years as conditioning variables, with the additional effect of separating the results obtained from GS on one side from those for the other databases on the other side. One can see that the evolution, for all databases, is relatively constant over time; but one can nevertheless notice that except on the last search, the number of references retrieved by GS increases constantly over time (see Figure 1a). When decomposing GS results by reference year, the averages computed for 2009 show a more variable pattern than the other years (see Figure 1b), but the number of results remains in the same size order.

We may therefore conclude that there is little variation in the number of bibliographic references retrieved by the bibliographic tools when the same search is repeated over time. The variability observed in the results obtained by GS illustrates that this tool seems to be more volatile than the others even though the variation is still rather limited when compared to the total number of hits.

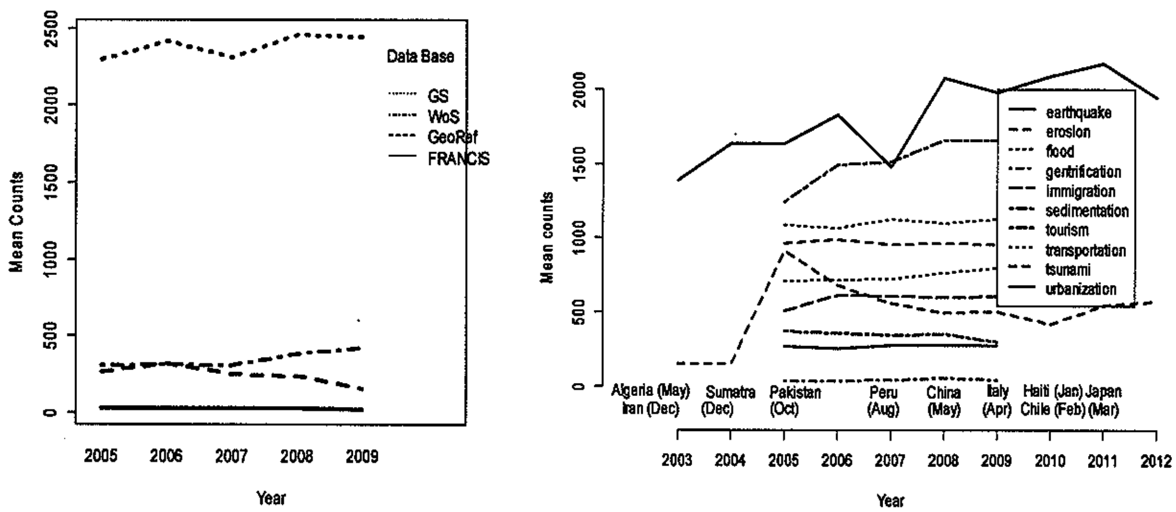


a) by DB b) by year of publication

Figure 1. Plots showing average results over different search times corresponding to different categories of a second variable

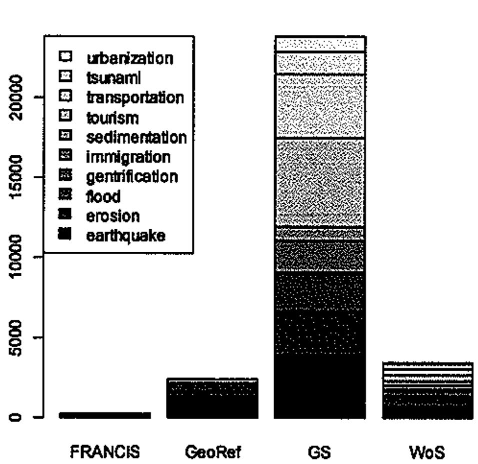
Performance of the search tools

The two figures below (2a and 2b) show the performance of the bibliographic tools over time.

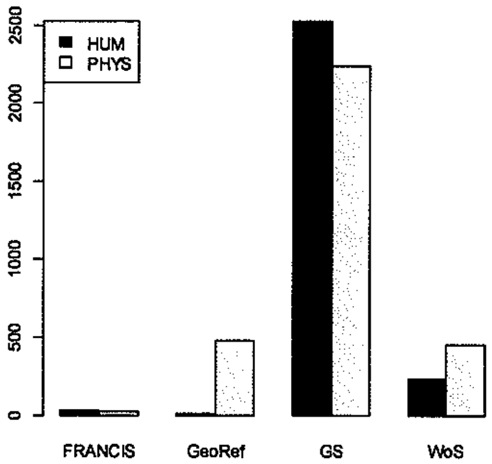


a) Conditioning variables: publication year and database

b) Conditioning variables: publication year and keyword



c) Conditioning variables: database and subfield



d) Conditioning variables: database and keyword

Figure 2. Plots showing conditional averages of the results for two explanatory variables

Figure 2a plots the average number of hits per year by publication and by bibliographic tool. It clearly shows that GS yields many more results than the other databases. This can also be observed in Figures 2c and 2d, where the averages conditioned not only on the bibliographic tools but also on, respectively, the keywords (2c) and the subfield (physical or human geography, 2d) are represented by stacked or juxtaposed bars.

Compared to GS, the number of references retrieved by the traditional databases is much lower: while GS reached averages between 2000 and 2500 in Figure 1a, these drop to a few hundred for WoS and GeoRef; FRANCIS provides the lowest number of results on average, around a few dozen. This was expected, as it is known that geographical literature only represents 8% of the references included in FRANCIS. However, overall, the huge difference between the numbers of results provided by GS and by the other databases makes us suspect a certain quantity of noise in the former—the nature of which will be explored further over the course of this study.

Figure 2b illustrates changes in the average numbers of hits across keywords over the years of publication. Most keywords remained relatively constant, but three of them, "earthquake," "tsunami," and "tourism," show divergent patterns: erratic spikes and valleys in the cases of the former two, and a continuous rise for the last. To get more insight on these particular keywords, the numbers of results for the keywords "earthquake" and "tsunami" was counted again for each of the four bibliographic tools over an enlarged period of publication (2003–2012). The corresponding averages are added to the interaction plot in Figure 2b. It appears that the variations are directly linked to important events—tsunamis and earthquakes—that occurred at corresponding time. The places where these events occurred are also indicated on the graph. For instance, as can be seen in graph 2b, the December 26, 2004, earthquake that provoked the tsunami in the Indian Ocean had a direct impact on the publications referring to tsunamis. The rise in the keyword "tourism" is probably due to the increasing tourist activity, and the scientific publications studying it, at a global level in the period under examination.

The significant number of results yielded by GS for the most popular keywords, "tourism," "transportation," and "earthquake" (Figure 2c), largely explains the overall leading position of GS in comparison to the other databases as well as its especially high performance in the subfield of human geography (Figure 2d). Proportionally to the results, at this stage of the analysis, one might conclude that GS seems to be more efficient in human geography while WoS performs better in physical geography and GeoRef and FRANCIS yield results proportionally in accordance with their main subfield orientations, respectively physical geography and human geography. Nevertheless, to assess the real performance of these search tools in the mentioned subfields, a more thorough analysis is needed; this matter will be further considered in the second part of the article.

In summary, the plots represented in Figure 2 tend to show that the average number of results depends on the chosen bibliographic tool and keyword as well as the subfield.

Case studies: "urbanization" and "sedimentation"

Treatment to compensate for noise

For the total five years results sample (2005–2009), Table 1 shows the initial number of references (No. of Refs.) and the proportions of them accounted for by the selected geographical references (Geogr. Ref.).

The initial number of results returned by GS was the highest, with 4791 references for "urbanization" and 4123 references for "sedimentation." However, only 57% of the GS results for "urbanization" refer to the geographical literature, and the percentage for "sedimentation" is slightly lower at 45%. The initial results provided by WoS were distinctly lower, with 585 references for "urbanization" and 1445 for "sedimentation," of which only 47% for "urbanization" and 42% for "sedimentation" were for geographical literature.

Table 1. Overall and geographical literature for the keywords "urbanization" and "sedimentation"

urbanization

	No. of Refs.	Geogr. Ref.
2005–2009		
GS	4791	2732 (57%)
WoS	585	275 (47%)
GeoRef	99	97 (98%)
FRANCIS	64	45 (70%)

sedimentation

	No. of Refs.	Geogr. Ref.
2005–2009		
GS	4123	1855 (45%)
WoS	1445	606 (42%)
GeoRef	1307	1265 (97%)
FRANCIS	39	33 (85%)

Although in third position for overall number of results, with 1307 results for "sedimentation" and 99 for "urbanization," the specialized DB GeoRef quite logically provides the highest percentage of geographical literature: almost 100% (98% for "urbanization" and 97% for "sedimentation"). FRANCIS also provides a good percentage of geographical literature—70% for "urbanization" and 85% for "sedimentation"—but a very low raw number of results.

Thus, with roughly comparable noise rates for the two main multidisciplinary tools, we determine that GS ultimately offers a higher number of potentially relevant results than WoS (and the other databases) for both keywords, especially for "urbanization." Further, after geographical reference selection, GeoRef outnumbers WoS for "sedimentation" with more than double the number of geographical references, whereas WoS leads GeoRef for "urbanization" results. FRANCIS is ranked far behind for both.

Overlap and specificity

For both selected keywords, "urbanization" and "sedimentation," the low values for *traditional overlap* (TO) indicate a high difference between the retrieved geographical references over five years (2005–2009) for each pair of bibliographic tools (Table 2). "Sedimentation" percentages show a slightly reduced distance between WoS and GS (25%), GeoRef and GS (33.4%), and WoS and GeoRef (27.5%). However, the distance between FRANCIS and the other BTs is very large, particularly for GS, with very low values for both keywords: 1.1% for "urbanization" and 1.3% for "sedimentation."

Table 2. Results of the bibliographic tool overlap analysis (TO, RO in A, and RO in B— %)

%	*WoS - GS*		*GeoRef- GS*		*FRANCIS - GS*		*WoS - GeoRef*		*FRANCIS - GeoRef*		*FRANCIS - WoS*	
'05-'09	urbaniz.	sedim.	urbaniz.	sedim.	urbaniz.	sedim.	urbaniz.	sedim.	urbaniz.	sedim.	urbaniz.	sedim.
TO	6.5	25	2	33.4	1.1	1.3	7.2	27.5	1.4	2	6.6	3.7
RO in A	66.5	82	56.7	62	68.8	75.8	9	66.7	5	75.7	44.4	69.7
RO in B	6.7	26.8	2	42	1.1	1.3	25.8	32	2.1	2	7.3	3.8

With regard to **GS**, the percentage of ***Relative overlap (RO) in A*** indicates that GS overlaps WoS and FRANCIS very well for the keyword "sedimentation," at respectively 82% and 75.8% over the study period. For "urbanization," GS also overlaps FRANCIS and WoS well, at respectively 68.8% and 66.5%. To a lesser extent, GeoRef is relatively well overlapped by GS for both keywords, with 62% for "sedimentation" and 56.7% for "urbanization."

In contrast, the percentage of ***Relative overlap (RO) in B*** shows that the traditional DBs overlap very few references from GS, except for the keyword "sedimentation," which is moderately well overlapped by GeoRef (42%) and poorly by WoS (26.8%). The very small values for RO in B are partly due to the very different number of results provided by the bibliographic tools.

Regarding **GeoRef,** RO in A shows that for "sedimentation," this DB overlaps FRANCIS very well, with 75.7% and WoS well, with 66.7%, but that there is very little overlap for "urbanization," with 5% for FRANCIS and 9% for WoS. Besides, RO in B values show that GeoRef is only poorly recalled by WoS, with 32% for "sedimentation" and 25.8% for "urbanization."

FRANCIS is well overlapped by WoS for "sedimentation," with RO in A of 69.7%, and moderately for "urbanization," with RO in A of 44.4%. As expected, however, FRANCIS overlaps very few references from GeoRef and WoS, with RO in B ranging from 2% to 7%. It is worth mentioning as well that FRANCIS is 100% overlapped by WoS for 2008 and 2009, GeoRef for 2008, and GS for 2006 (yearly results not shown).

In short, taking into account our findings, we can say that GS is a bibliographic tool that performs well at overlapping retrieved references from traditional DBs, at least for the two selected keywords and perhaps also for the others, while the traditional DBs overlap only a moderate number of documents provided by GS. GeoRef overlaps FRANCIS and WoS very well for "sedimentation," whereas WoS covers about one-quarter of the documents provided by GeoRef for both keywords and by GS for "sedimentation."

The specific results by search tool are the corollary of the overlaps (Figure 3 and Table 3).

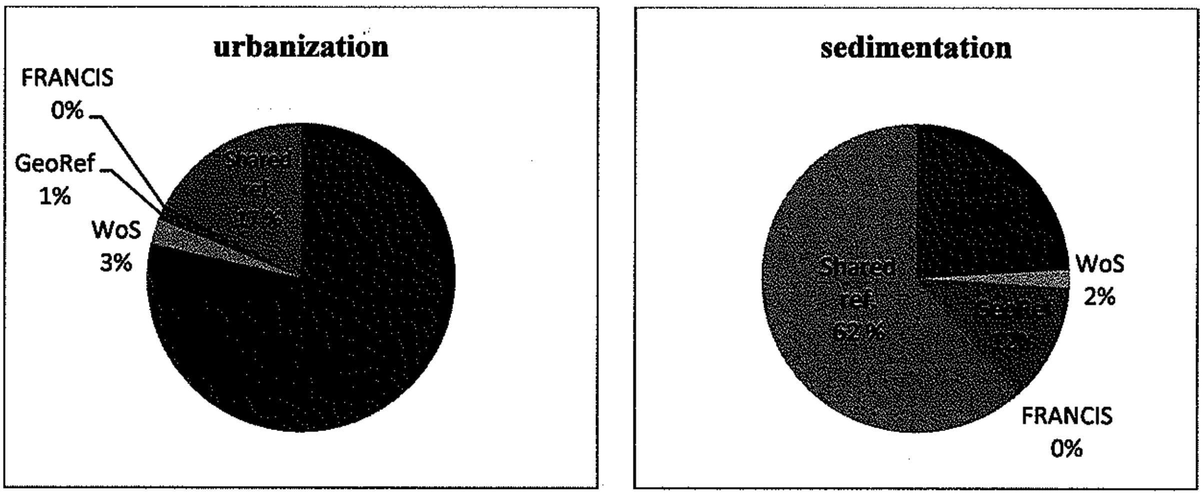


Figure 3. Unique references provided by each bibliographic tool

In all, 79% (2473) of the references for "urbanization" are unique to GS, and 24% (904) for "sedimentation." For the latter, a significant number of unique items are also found in GeoRef: 466 references, or 12%.

The percentage of references shared between at least two bibliographic tools is 17% for "urbanization" and 62% for "sedimentation." This important difference can be interpreted as testimony to GS's efficiency in retrieving additional unique references in human geography.

Table 3. Unique references and associated types of literature for each bibliographic tool

2005–2009	Unique Ref/DB	Journal Articles	Conf. Proc.	Theses	Reports	Unpubl. Work	Patents	Maps	Book/Book Chapter
urbanization									
GS	2473	1908	249	99	38	5	--	--	174
WoS	83	83	--	--	--	--	--	--	--
GeoRef	39	19	11	1	6	--	--	--	2
FRANCIS	11	11	--	--	--	--	--	--	--
sedimentation									
GS	904	393	282	107	47	--	5	--	70
WoS	72	71	1	--	--	--	--	--	--
GeoRef	466	243	147	30	26	--	--	2	18
FRANCIS	6	6	--	--	--	--	--	--	--

Table 3 details the number of unique items provided by each BT and the corresponding types of literature. It appears that grey literature (conference proceedings, theses, reports, and to a lesser extent patents, unpublished works, and maps) and books or book chapters are only returned by GS and GeoRef. Given the significant number of conference proceedings covered by WoS (150,000), we may be surprised at finding a low number of this type of document in WoS.

The percentages of journal articles retrieved by GS are roughly equivalent to those from GeoRef: for "urbanization," 77% of unique items in GS and 46% in GeoRef are journal articles, while for "sedimentation," 43% of unique items in GS and 52% in GeoRef are journal articles.

The percentage of references accounted for by grey literature for "urbanization" is low in GS (16%) and equivalent to that for journal articles in GeoRef (46%); and for "sedimentation," 49% in GS and 44% in GeoRef.

Books or book chapters represent only a few percent of the total, in all cases: for "urbanization," 7% in GS and 5% in GeoRef, and for "sedimentation," 8% in GS and 4% in GeoRef.

Discussion and Conclusion

With reference to the initial questions asked in this study, our results show that:

1) The statistical approach applied to the data consolidates our hypothesis that GS leads the other tools widely on number of results, independently of keyword, subfield, year of publication, or time of search. In contrast, FRANCIS yielded a very low number of results, classifying it as the least useful of the tools in both human and physical geography. The interest of this database is possibly confined to more local and/or non-English literature.
2) From the case study (of "urbanization" and "sedimentation"), it appears that GS remains on top even after removing duplicates and selecting geographical references (noise treatment). It is worth noting that GS's noise rates are similar to or even lower than those of WoS, the other international, multidisciplinary tool assessed. Both tools provided one valid reference out of two. In contrast, the specialized DB GeoRef always retrieves almost 100% geographical literature.
3) With regard to overlap, we found that WoS is highly covered by GS, with values (66.5% and 82%) close to those found by Neuhaus and his collaborators (2006) (77%) and by Mikki (2009) (85%). With respect to the specialized DB GeoRef, although GS's recall performance is reduced, our values (56.7% and 62%) are similar to the most recent ones (55%) found by Musser (2008). That strengthens the argument that GS's coverage has improved since previous work investigating this point (Neuhaus et al., 2006, with 26% coverage).
4) By retrieving a large number of unique references, GS may yield additional information. Like GeoRef but unlike WoS, GS offers a broad range of references (journal articles of course, but also additional types of literature such as reports, theses, conference proceedings and books/book chapters). This additional literature can be very useful to researchers, and can obviously be acceptable as academic literature. Examples of titles present among the unique hits provided by GS are: *IAHS Publications—Proceedings and Reports Series*, *AGU Spring & Fall Meeting Abstracts*, *Geophysical Research Abstracts*, *Geological Society of America—Abstracts*, and *EGU General Assembly Abstracts*. However, some scholars are selectively interested only in peer-reviewed articles and consider that the traditional DBs are the unique way to quickly access to all peer-reviewed articles. But the notable presence of grey literature and books or books chapters is surprisingly not the main explanation for additional hits in GS: the number of unique "journal articles" is impressive. After examination of the lists of unique references, we are currently performing a study to verify the hypothesis that a significant proportion of these articles are published in more international peer-reviewed journals (e.g., the growing amount of literature in English from publishers in Asian countries).
5) The performance of the bibliographic tools has to be considered by subfield (human or physical geography). The statistical approach suggests that the number of human-geographical references is higher in GS, whereas GeoRef is clearly geared towards physical geography. However, in absolute terms, GS should be useful to researchers in both fields because of the large number of additional references it provides. However, our results also show that GeoRef provides a significant number of unique items in Physical Geography, putting us in agreement with Mikki

(2010), who says that GeoRef, which is highly specialized in geosciences, provides titles and abstracts translated from non-English publications, which could explain the significant number of additional items.

6) During the nine-month period of the study, the number of references generated by traditional DBs for the years 2005–2009 proved stable, with an occasional slight increase. In comparison, GS data encountered more variation, and a detailed analysis of the references could possibly reveal even more important turnover within the lists. Nonetheless, there is such a big distance in raw numbers of findings between GS and the traditional DBs that our results and interpretations would not be affected by such an analysis.

On the basis of our findings, and in agreement with Meier and Conkling (2008), we think that GS provides a viable alternative to geographers whose institutions cannot afford or do not wish to pay for access to commercial DBs. When access to commercial DBs is possible, the distance between the results provided by the analyzed tools suggests that geographers should test their specific keywords to determine if the usage of GS remains supplementary or if it has become their best primary bibliographic tool with respect to their individual research areas.

It should be noted that GS does not present only advantages, however. Previous studies have pointed negative aspects such as variable reference format and incorrect information regarding authors, journals, and citations (Bar-Ilan 2006; Bar-Ilan *et al.* 2007; Gardner and Eng 2005; Jacsó 2005). Criticism of the search interface no longer applies, as Google search mode is increasingly being used even in scholarly libraries; and the simplicity of the search interface (Meier and Conkling 2008) has come to be appreciated. However, simplified queries bring a large number of responses, and the processing or sorting of results remains very time-consuming in GS both due to the overall amount of data and to limited functionality (e.g., there may be limited opportunity to refine results or there may be no mass export function to reference management software).

In conclusion, since the price of commercial DBs is continuously increasing (Chen 2010a; Cusker 2013) and the budgets of academic libraries are often restricted and becoming more so, we think the free access provided by GS makes it a paramount asset for accessing the academic literature.

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