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ORIGINAL ARTICLE

Estimates of Arab world research productivity associated with groundwater: a bibliometric analysis

Shaher H. Zyoud[1] · **Daniela Fuchs-Hanusch**[1]

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Abstract The sustainable management of groundwater resources is a pressing necessity for most countries. As most of the Arab world is facing severe water scarcity, threats of depletion of non-renewable groundwater, and problems of pollution and salt-water intrusions into groundwater aquifers, much effort should be devoted to eliminate these dangers in advance. This work was devoted to bring up insights into Arab world research activities in groundwater, which is a crucial task to identify their status and can help in shaping up and improving future research activities. A bibliometric analysis has been conducted to track these activities. The study identified 1417 documents which represent 3.3% of global research productivity. Egypt was the most productive country (313; 22.1%), followed by Saudi Arabia (254; 17.9%). Total citations were 9720 with an average of 6.9. The *h*-index of the retrieved documents was 39, and the highest one was 22 for Egypt. The most common subject category was Environmental Science, and the most productive journal was Arabian Journal of Geosciences (99; 7.0%). In international research collaboration, France was the most collaborated country with Arab world (125; 8.8%), followed by the United States (113; 8.0%). The most productive institution was King Abdul-Aziz University, Saudi Arabia (66; 4.7%). The outcomes shows remarkable improvements in groundwater research activities originated from the Arab world. Even though, constructive efforts should be pursued vigorously to bridge the gaps in groundwater-based research. Moreover, promotion of better evaluation tools to assess the risks arising from the mismanagement of groundwater resources is required urgently.

Keywords Groundwater · Bibliometric · Scopus · Citation · Impact factor · Arab world

✉ Shaher H. Zyoud
shaherzyouds@gmail.com

Daniela Fuchs-Hanusch
fuchs-hanusch@tugraz.at

[1] Institute of Urban Water Management and Landscape Water Engineering, Graz University of Technology, Stremayrgasse 10/I, 8010 Graz, Austria

Introduction

Groundwater is the subsurface water that fully saturates all fissures and pores in rocks and soils, and occurs as an output of the hydrologic cycle, which is used to represent the continuous movement of water in the environment (Giordano 2009; Mitchell et al. 2001). It is formed by excess rainfall (total precipitation minus surface runoff and evapotranspiration) that soaks deeper into the ground until it reaches the saturated zone to form what is called groundwater formations (Bouwer 2000). Groundwater is a primary source of fresh water in many parts of the world (Rodell et al. 2009), and it comprises more than 95% of the world's freshwater resources, if we ignore water frozen in glaciers and polar ice (Alley 2006). In arid and semi-arid regions, it is considered the most important water resource, and its quality is of utmost concern (Jing et al. 2014). It is often the most or only feasible safe drinking water source in remote and low-resource areas (Abramson et al. 2014). Traditionally, it has been considered safe for human consumption without undergoing conventional drinking water treatment (Yates et al. 1985).

The exploitation of groundwater resources for human use dates from the earliest civilizations, but massive resource development has been largely restricted to the past

50 years (Foster and Chilton 2003). The development of groundwater resources produced considerable social and economic benefits since it is playing a significant role in urban water supply, rural livelihood (Foster and Chilton 2003), and in the health of many ecosystems (Alley et al. 2002). Calls for groundwater resources management and international attention to groundwater are substantial issues since the process of developing and managing this vital resource in a sustainable mode discomposes many challenges (Zuppi 2008). The most challenges that dominate groundwater use are: depletion due to overdraft, pollution due to agricultural, industrial and other human activities (Shah et al. 2000), saltwater intrusion (Koundouri 2004) and decreasing of discharge to rivers, springs and wetlands (Custodio 2010).

Challenges of managing water resources are more severe and widespread in developing countries rather than advanced ones, and the vast majority of projects adopting methodologies of advanced approaches for groundwater management and vulnerability assessment have been carried out in first world countries (Mende et al. 2007). The Arab countries are considered as developing countries (Medany 2008), and most of their lands are classified as hyper-arid, semi-arid and arid land zones that are characterized by low and limited water resources (Medany 2008). In the last decade, promising initiatives from Arab world are devoting more efforts to improve groundwater management, which include for examples: groundwater monitoring using new advances in remote sensing technologies (Chartres and Varma 2010), cooperation in the North Western Sahara Aquifer system (Benblidia 2005), and developing policies for groundwater protection from pollution by anthropogenic activities (UNEP 2010). Furthermore, a noticeable increase in scientific research activities in this regard has been observed in these countries.

Studies of analyzing scientific research productivity in different disciplines at country, region and/or global levels have been performed by researchers during the last periods to examine the status of research and to evaluate its performance (Fu et al. 2010; 2013; Zheng et al. 2015; Zyoud and Fuchs-Hanusch 2015; Zyoud et al. 2016a, b; Zyoud et al. 2015). By reviewing the obtainable literature and to the best of our knowledge, there is a lack of data regarding the evaluation of scientific output in the field of groundwater research at Arab world level. Globally, a study conducted by Schwartz et al. (2005) is available in which they described patterns of evolution of research strands in the hydrologic sciences and examined issues of impact and innovation in groundwater research using bibliometric data and citation analysis. This study was limited to articles published in Water Resources Research journal only (Schwartz et al. 2005). The proposed study will focus on measuring and analyzing the scientific productivity of groundwater research originating from the Arab countries. This analysis will give a better perception of the current and future status of research in groundwater at this region level.

The Arab world is extending from the Indian to the Atlantic Ocean, and from Black and Caspian Seas to Sub Saharan Africa. In 2010, it was the home of 359 million people, and in 2050, it is projected to reach nearly 600 million (Mirkin 2010). The people of this region are having many similarities and dissimilarities. They share language, culture, and religion but they are also subject to social, political and economic distinctions (Boutayeb et al. 2012). Particularly, in the oil-rich Arab countries, education sectors, living standards and health services have been noticeably improved over the last periods, which were accompanied by a relative increase in scientific output (Benamer et al. 2009). The mapping of Arab world research activities that are related to groundwater will assist in evaluating its contribution to the global literature, assessing the commitment to the state of science in this field and the exerted efforts for development and research, which by the end can help researchers in identifying and undertaking new directions of research and can improve the future research investments. The most common research techniques used to track the scientific research activities are bibliometric methods (Li et al. 2008). They are a well-known research tools for systematic analyses (van Raan 2005), which mostly employed to procure bibliographical data within a specific field, institute, topic, journal, authors or country by utilizing quantitative analyses and statistics methods (Wallin 2005). Furthermore, they can be used in creating pronouncements about qualitative performance indicators of research activities (Wallin 2005).

This study aimed to analyze research output originated from Arab region and related to groundwater research, measuring rates of growth, research collaborations figures, most prolific journals, authors and institutions, and most cited works depending on data harvested from Scopus database. This work can be deemed as an informative assessment that can assist in creating detailed insights and in mapping of most important bibliometric performance indictors associated with research activities in highly remote and critical field such as groundwater research.

Methods

Search strategy

This study counted on data synthesized from Scopus database for a period including all previous years up to December 31, 2015, with an aim to get an integrated view

on the modality of research output from Arab world in the field of groundwater. An inclusive search has been performed using SciVerse, Scopus, which is one of the largest databases, abstracts and citations of peer-reviewed literature. This research database includes nearly 60 million records, and over than 21,500 peer-reviewed journals (Elsevier 2016). It is deemed as one of the most reliable bibliographical source and has been mostly employed to reveal patterns of scientific research. Scopus database is conjugating the features of both PubMed and Web of Science search databases, and is larger than Web of Science and more accurate than Google Scholar (Falagas et al. 2008). The search output from Scopus can be displayed in list of 20–200 items per page, and the extracted files can be exported to Excel, and these results can be refined by document type, author name, source title, publications per year, and/or subject area, and a new search can be initiated within the results (Falagas et al. 2008).

To meet the objectives of this study, the following keywords which have been selected from related studies in groundwater (Al-Adamat et al. 2003; Almasri and Kaluarachchi Almasri and Kaluarachchi 2004, 2005; Bakalowicz 2005; Edmunds et al. 2003; Garmes et al. 2002; Storey et al. 2003; Tahaikt et al. 2007) were entered into the Scopus as article titles: "groundwater", "groundwater", "ground water", "ground waters", and "water ground". The effective keywords were: "groundwater*", "ground water*" and "water ground". The term "water ground" refers to expressions mentioned in the article titles such as "surface water/ground water; salt water–ground water, etc.". The advanced search captures the word "water" from the first term, and the word "ground" from the second term to form the term "water ground". The asterisk (*) in the second word of the used terms has been used as a wild card character to simplify the search and to make it more comprehensive since this format will track all possible forms of the used terms (i.e., it was more inclusive when ("ground water*") search term was used in comparison with the use of ("ground water"). All subject areas within Scopus database which include: life, health, social and physical sciences were chosen. Furthermore, all types of documents in Scopus database will be considered excluding the erratum type of documents. The twenty-two Arab countries: Saudi Arabia; Egypt; Jordan; Palestine; Lebanon; Qatar; Bahrain; Kuwait; Morocco; Tunisia; Syrian Arab Republic; United Arab Emirates; Iraq; Sudan; Yemen; Algeria; Comoros; Djibouti; Libya; Mauritania; Oman; and Somalia will be employed as country keys during the search process.

The formula in the advanced search for Article titles related to groundwater will be as follows:

TITLE("groundwater*" OR "ground water*" OR "water ground") AND PUBYEAR<2016 AND (EXCLUDE(DOCTYPE, "er")) AND (LIMIT-TO(AFFILCOUNTRY, "Egypt") OR LIMIT-TO(AFFILCOUNTRY, "Saudi Arabia") OR LIMIT-TO(AFFILCOUNTRY, "Morocco") OR LIMIT-TO(AFFILCOUNTRY, "Tunisia") OR LIMIT-TO(AFFILCOUNTRY, "Jordan") OR LIMIT-TO(AFFILCOUNTRY, "Algeria") OR LIMIT-TO(AFFILCOUNTRY, "Kuwait") OR LIMIT-TO(AFFILCOUNTRY, "Palestine") OR LIMIT-TO(AFFILCOUNTRY, "Oman") OR LIMIT-TO(AFFILCOUNTRY, "United Arab Emirates") OR LIMIT-TO(AFFILCOUNTRY, "Syrian Arab Republic") OR LIMIT-TO(AFFILCOUNTRY, "Lebanon") OR LIMIT-TO(AFFILCOUNTRY, "Sudan") OR LIMIT-TO(AFFILCOUNTRY, "Yemen") OR LIMIT-TO(AFFILCOUNTRY, "Libyan Arab Jamahiriya") OR LIMIT-TO(AFFILCOUNTRY, "Iraq") OR LIMIT-TO(AFFILCOUNTRY, "Bahrain") OR LIMIT-TO(AFFILCOUNTRY, "Mauritania") OR LIMIT-TO(AFFILCOUNTRY, "Qatar") OR LIMIT-TO(AFFILCOUNTRY, "Comoros") OR LIMIT-TO(AFFILCOUNTRY, "Djibouti") OR LIMIT-TO(AFFILCOUNTRY, "Somalia")).

The following information can be collected as outcomes, and further analysis among these outcomes can be carried out (a) total research productivity during all previous years up to December 31, 2015; (b) collaboration figures by country and/or by region; (c) journals where Arb researchers mostly published their researches; (d) most prolific institutions and authors; (e) citation rates of the published works and most cited documents. The search has been carried out within one time interval (July 24, 2016) to eliminate the bias which may happen as a consequence of daily updating of Scopus database.

Indices of research productivity

This study will arrange the outputs that are related to: countries, journals, areas of interest, institutions, most cited articles, and most prolific authors in descending order according to the formula of standard competition ranking (SCR) in combination with their bibliometric performance indicators (i.e., the one with the highest performance will be on the top and so on). The study will evaluate the performance of all Arab countries while for the other outputs, the only top twenty ranked outputs will be considered and in any case, any outputs have attracted the same ranking, a jump in numbering for the subsequent one will be adopted.

The *h*-index, which is a simple single number incorporating both quantity (publication) and quality (citation scores), was employed to display the total citations received for published documents (Egghe 2006). It was introduced in 2005 by Hirsch as a useful tool index to further characterize the importance, significance and broad

impact of a researcher's cumulative research contributions (Hirsch 2005). The *h*-index is a country's number of articles (*h*) that have received at least *h* citations and it is applicable also to journals and scientists and can be used to quantify both country scientific productivity and scientific impact (Hirsch 2005). To simplify its significance; it can be said: a country with an *h*-index 15 has published 15 documents and each document has attracted at least 15 citations. To demonstrate the frequency with which the "average article" in a specified journal has been cited in a particular year or period, the impact factor (IF) as one of quantitative tools proposed by The Journal Citation Report (JCR) for ranking, evaluating, categorizing, and comparing journals (Web of Science 2016) has been used.

Statistical analysis

Statistical package for social sciences (SPSS) program has been used to process the generated data from Scopus database statistically. The statistical analysis will calculate the descriptive statistics such as median, mean and sum. The median (Q1–Q3: interquartile range) will be used to represent the variables that are not normally distributed such as the number of citations. The categorical data will be represented as numbers with percentages.

Bibliometric maps

Bibliometric maps and network visualization techniques using VOSviewer software (van Eck and Waltman 2010) will be employed to shed the light on the most topics of concern. This software creates maps based on data of network using the "visualization of similarities" mapping and clustering technique and designed to primarily be used for analysis of bibliometric networks (Zeraatkar 2013). The analysis of co-occurrence of keywords (i.e., all types of keywords: author keywords and index keywords) with a threshold of minimum number of occurrences of a keyword is five, which will be done and the results will be displayed in two forms: density visualization and network visualization. In maps of density visualization, the text size indicates the contribution of the item (i.e., the larger text, the higher contribution) and the distance between the items indicates the strength of the links between them (i.e., the closer distance indicates stronger links) which can be translated into colors in the format of red–green–blue and the red color is the indicator of the hot area where many linkages exist (Zeraatkar 2013). In network visualization, the observations are assigned to clusters, where the observations in each cluster are similar to one another with respect to attributes of interest (Tryfos 1998).

Results

The total number of documents extracted from Scopus database with terms related to "groundwater" in the article titles, without imposing limitations to search for specific countries was 43,657 documents. An exclusion for 252 documents published as erratum leads to a net total of 43,405 documents. This figure represents the total global research productivity in groundwater filed. When the search was limited to Arab countries, the produced figure was 1417 documents (3.3% from the total global research productivity in groundwater field). This figure includes 1219 (86.0%) documents as original journal articles and articles in press, 147 (10.4%) as conference papers, 20 (1.4%) as reviews, 31 (2.2%) documents classified as other types of publications, such as book chapter, notes, short survey, editorial or letter. As documented in Scopus database, the first published article with author's affiliation to Arab world and related to groundwater research was entitled "prospecting for ground water by induced electrical polarization" (Vacquier et al. 1957). It was published in Geophysics journal in 1957, and one of the co-authors (Kintzinger, P. R.) was from The Desert Institute; Mataria; Egypt. Figure 1 shows the distribution of documents published per year from Arab world with comparison to evolution of annual publications at global level. Published documents in English language were the dominant ($n = 1356$; 95.7%). It was followed distantly by French ($n = 81$; 5.7%), Spanish ($n = 13$; 1.0%) and Arabic language ($n = 9$; 0.6%).

Analyzing of data at country level as displayed in Table 1, shows that Egypt was the most productive country (313 documents; 22.1%), followed by Saudi Arabia (254; 17.9%), and Tunisia (170; 12.0%). No data related to groundwater were published from Djibouti, Somalia, and

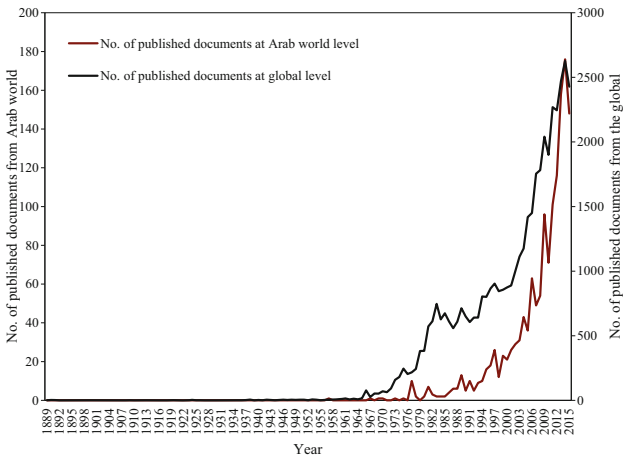

Fig. 1 No. of published documents at Arab world level in fields of research related to groundwater with comparison to research productivity from the Global

Table 1 Bibliometric analysis of 1417 documents published by Arab world in groundwater during a period of time extended from 1957 to end of 2015

SCR[a]	Countries	No. of published documents (%)	*h*-index	Total citations	Median of citations (Q1-Q3)[b]	Average of citations	Collaboration with other countries	Number of documents with international authors (%)[c]	Most collaborated country	No. of documents with most collaborated country (%)
1st	Egypt	313 (22.1)	22	1805	2 (0–7)	5.77	32	145 (46.0)	Saudi Arabia	44 30.0)
2nd	Saudi Arabia	254 (17.9)	18	1387	2 (0–7)	5.46	36	106 (42.0)	Egypt	44 (42.0)
3rd	Tunisia	170 (12.0)	16	1110	2.5 (0–7)	6.53	30	76 (45.0)	France	33 (43.0)
4th	Morocco	164 (11.6)	18	1314	4 (1–11)	8.01	21	104 (63.0)	France	54 (52.0)
5th	Jordan	111 (7.8)	17	1115	6 (1–12)	10.05	29	52 (47.0)	Germany	18 (35.0)
6th	Algeria	104 (7.3)	12	559	1 (0–5)	5.37	12	38 (37.0)	France	23 (61.0)
7th	United Arab Emirates	68 (4.8)	10	289	1 (0–5.75)	4.25	19	45 (66.0)	Egypt	14 (31.0)
8th	Oman	58 (4.1)	13	467	4 (1–12.25)	8.05	19	35 (60.0)	India	6 (14.0)
9th	Kuwait	57 (4.0)	10	278	3 (0–7)	4.87	5	5 (9.0)	France	−1 (20.0)
									Hungary	−1 (20.0)
									India	−1 (20.0)
									Sudan	−1 (20.0)
									United Kingdom	−1 (20.0)
10th	Palestine	50 (3.5)	16	714	6.5 (1–18)	14.28	14	29 (58.0)	United States	14 (48.0)
11th	Syrian Arab Republic	39 (2.8)	9	302	4 (1–9)	7.74	11	20 (51.0)	Germany	9 (45.0)
12th	Iraq	36 (2.5)	4	36	0 (0–1)	1.0	8	14 (39.0)	Germany	5 (36.0)
13th	Lebanon	32 (2.2)	8	644	3.5 (1–11.75)	20.13	10	12 (38.0)	France	4 (33.0)
14th	Sudan	25 (1.8)	5	120	1 (0–4)	4.80	13	13 (52.0)	United States	3 (23.0)
15th	Yemen	16 (1.1)	5	114	3 (0–7.75)	7.13	9	13 (81.0)	Malaysia	5 (38.0)
16th	Libyan Arab Jamahiriya	15 (1.0)	3	36	0 (0–3)	2.40	5	7 (47.0)	India	−3 (43.0)
									Morocco	−3 (43.0)
17th	Bahrain	11 (0.8)	5	76	4 (1–10)	6.90	1	1 (9.0)	India	1 (100.0)
18th	Qatar	6 (0.4)	2	8	1.5 (0–2.25)	1.33	7	3 (50.0)	United States	2 (67.0)
19th	Mauritania	2 (0.1)	–	–	–	–	–	–	–	–
20th	Djibouti	–	–	–	–	–	–	–	–	–
20th	Somalia	–	–	–	–	–	–	–	–	–
20th	Comoros	–	–	–	–		–	–	–	–

SCR Standard competition ranking, *Q1–Q3* lower quartile–upper quartile

[a] Equal countries have the same ranking number, and then a gap is left in the ranking numbers

[b] For the small number of articles, the interquartile range was not available

[c] Percentage of documents with international authors (i.e., from other Arab and non-Arab countries) out of the total number of documents for each country

Comoros. The total number of citations at the time of synthesizing data was 9720, with an average of 6.9 citations per document. The median (interquartile range) of citation was 2 (0.0–8.0). The highest median of citations was 6 (1.0–18) for Palestine, followed by 6 (1.0–12.0) for Jordan. The total *h*-index of the retrieved documents was 39, which means that 39 documents had been cited at least 39 times at the time of data analysis. The highest *h*-index was 22 for Egypt, followed by 18 for each of Saudi Arabia and Morocco, 17 for Jordan, and 16 for each Tunisia and Palestine. Saudi Arabia was the most collaborated country with other countries, followed by Egypt and Tunisia.

Table 2 Collaborations between Arab countries and foreign countries in Groundwater research

Region/Countries[a]	No. of documents (%)	*h*-index	Total citations	Median of citations (Q1–Q3)[b]	Average of citations
Western Europe	329 (23.2)	25	3065	4 (1–11)	9.32
France	125 (8.80)				
Germany	76 (5.40)				
United Kingdom	32 (2.30)				
Netherlands	24 (1.70)				
Italy	20 (1.40)				
Portugal	20 (1.40)				
Spain	17 (1.20)				
Belgium	15 (1.10)				
Sweden	11 (0.80)				
Switzerland	8 (0.60)				
Denmark	5 (0.40)				
Greece	5 (0.40)				
Austria	4 (0.30)				
Norway	2 (0.10)				
Cyprus	1 (0.07)				
Iceland	1 (0.07)				
Ireland	1 (0.07)				
Northern America	123 (8.70)	25	1882	7 (2–20)	15.3
United States	113 (8.0)				
Canada	12 (0.85)				
Asiatic Region	99 (7.0)	12	551	3 (0–7)	5.56
India	32 (2.30)				
Japan	23 1.60)				
Malaysia	15 (1.10)				
China	12 (0.85)				
Pakistan	4 (0.30)				
South Korea	3 (0.20)				
Uzbekistan	3 (0.20)				
Bangladesh	2 (0.10)				
Taiwan	2 (0.10)				
Thailand	2 (0.10)				
Brunei Darussalam	1 (0.07)				
Hong Kong	1 (0.07)				
Indonesia	1 (0.07)				
Nepal	1 (0.07)				
Sri Lanka	1 (0.07)				
Viet Nam	1 (0.07)				
Middle East	21 1.50)	7	171	4 (1.5–15.5)	8.14
Turkey	14 (1.0)				
Israel	5 (0.40)				
Iran	3 (0.20)				
Eastern Europe	19 (1.30)	8	248	3 (1–17)	13.05
Poland	6 (0.42)				
Russian Federation	4 (0.30)				
Hungary	3 (0.20)				
Romania	3 (0.20)				
Bulgaria	1 (0.07)				

Table 2 continued

Region/Countries[a]	No. of documents (%)	*h*-index	Total citations	Median of citations (Q1–Q3)[b]	Average of citations
Czech Republic	1 (0.07)				
Slovakia	1 (0.07)				
Africa	18 (1.30)	6	116	4.5 (0.75–11.25)	6.44
South Africa	5 (0.40)				
Cameroon	3 (0.20)				
Senegal	3 (0.20)				
Ethiopia	2 (0.10)				
Benin	1 (0.07)				
Ghana	1 (0.07)				
Niger	1 (0.07)				
Nigeria	1 (0.07)				
Rwanda	1 (0.07)				
Uganda	1 (0.07)				
Pacific Region	16 (1.13)	6	122	3.5 (2–7.75)	7.62
Australia	16 (1.13)				
Latin America	6 (0.42)	2	141	1 (0–36.25)	23.5
Trinidad and Tobago	3 (0.20)				
Brazil	1 (0.07)				
Chile	1 (0.07)				
Mexico	1 (0.07)				

Q1–Q3 lower quartile–upper quartile

[a] The study identified 531 (37.5%) documents with 60 countries in Arab-foreign country collaborations

[b] Total exceeds 37.5% as data are overlapping due to multi-country collaboration

[c] No. of documents as a result of Arab–Arab collaborations: 114 documents (8.0%)

The study identified, as shown in Table 2, 531 (37.5%) documents with 60 countries in Arab-international collaborations. At country level, the highest rate of collaboration was between Arab scholars and researchers from France ($n = 125$; 8.8%), followed by the United States ($n = 113$; 8.0%), Germany ($n = 76$; 5.4%), United Kingdom ($n = 32$; 2.3%) and India ($n = 32$; 2.3%). At regional level, the highest rate of collaboration was with Western Europe (329 documents; 23.2%), followed by Northern America (123; 8.7%) and Asiatic region (99; 7.0%). Furthermore, the highest rate of citations was attained for published research as a result of collaboration between Arab world and Western Europe (3065 citations), followed by collaboration with Northern America (1882 citations). Table 3 shows areas of interests of the published research, Environmental Science was the most with 916 documents (64.6%), followed by Earth and Planetary Sciences (615; 43.4%), Agricultural and Biological Sciences (212; 15.0%) and Engineering (206; 14.5%).

Figures 2 and 3 illustrate density and visualization maps of all keyword co-occurrence analysis related to groundwater research in Arab world with a threshold of five as a minimum number of occurrences of a keyword. Out of 8053 keywords, 889 meet the threshold and the number of co-occurrence links has been calculated. The keywords with the largest number of links have been selected. A five clusters were generated as shown in Fig. 3: Cluster number 1 (red color) included 277 items, and the most frequent term was ground water (800 occurrences), cluster number 2 (green color) included 262 items, and the most frequent term was groundwater pollution (234 occurrences), cluster number 3 (blue color) included 189 items, and the most frequent term was hydrochemistry (151 occurrences), cluster number 4 (yellow color) included 88 items, and the most frequent term was irrigation (119 occurrences), cluster number 5 (violet color) included 73 items, and the most frequent term was water quality (318 occurrences).

The retrieved documents were published in 143 peer-reviewed journals. Table 4 shows the ranking of the top twenty journals. Ninety-nine documents (7.0%) were published in Arabian Journal of Geosciences, (69; 4.9%) were published in Environmental Earth Sciences and (50; 3.5%) in Environmental Geology. The majority of journals listed in the list of top twenty ranking journals had an official impact factor and were listed in the JCR 2015. In Table 5, a list of top twenty most cited articles from 1957

Table 3 Ranking of top 20 areas of interests of the published research from Arab world in the field of groundwater

SCR[a]	Areas of interests	No. of published documents (%)[b]
1st	Environmental Science	916 (64.6)
2nd	Earth and Planetary Sciences	615 (43.4)
3rd	Agricultural and Biological Sciences	212 (15.0)
4th	Engineering	206 (14.5)
5th	Chemistry	60 (4.2)
6th	Chemical Engineering	58 (4.1)
7th	Medicine	57 (4.0)
8th	Social Sciences	55 (3.9)
9th	Multidisciplinary	52 (3.7)
10th	Physics and Astronomy	51 (3.6)
11th	Materials Science	44 (3.1)
12th	Energy	42 (3.0)
13th	Computer Science	40 (2.8)
14th	Mathematics	25 (1.8)
15th	Biochemistry, Genetics and Molecular Biology	21 (1.5)
16th	Pharmacology, Toxicology and Pharmaceutics	13 (0.9)
17th	Immunology and Microbiology	4 (0.3)
18th	Business, Management and Accounting	3 (0.2)
18th	Veterinary	3 (0.2)
20th	Arts and Humanities	1 (0.1)
20th	Decision Sciences	1 (0.1)
20th	Economics, Econometrics and Finance	1 (0.1)
20th	Health Professions	1 (0.1)

SCR standard competition ranking

[a] Equal Areas of interests have the same ranking number, and then a gap is left in the ranking numbers

[b] Total exceeds 100% as data are overlapping due to multidiscipline interaction

to 2015 is displayed (Abu-Rukah and Al-Kofahi Abu-Rukah and Al-Kofahi 2001; Afonso et al. 2004; Al-Adamat et al. 2003; Almasri 2007; Almasri and Kaluarachchi 2004, 2005, 2007; Bakalowicz 2005; Ebraheem et al. 1997; Edmunds et al. 2003; El Khalil et al. 2008; Elmidaoui et al. 2001; Forkutsa et al. 2009; Garmes et al. 2002; Harari 1996; Storey et al. 2003; Sturchio et al. 2004; Subyani 2004; Tahaikt et al. 2007; Walha et al. 2007). Table 6 shows a list of top twenty most productive institutions from Arab world. The two most productive institutions were King Abdul-Aziz University, Saudi Arabia (66; 4.7%), followed by Ecole Nationale d'Ingenieurs de Sfax, Tunisia (64; 4.5%). Table 7 listed the top twenty most prolific authors from Arab world.

Discussion

The Bibliometric technique has been used over and over to track and analyze the scientific production and research trends in many disciplines (Daughton 2016; Sweileh et al. 2016; Tan et al. 2014; Zyoud et al. 2016a, b). It is used to evaluate, describe, monitor of research and to determine the impact of a technology and the effectiveness of an author or research organization, as well it serves as a monitoring tool to track the level of activity in a research field over time (Ziegler 2009). This type of analysis continues to be fundamental in constituting a useful complement for the judgments and opinions of experts in each field, assessing the outcomes of the scientific research activities, as well foreseeing how the research activities might progress (López-Muñoz et al. 2013). This analysis concentrated primarily on evaluating the impact of groundwater research at Arab world level among the global research, through a comprehensive analysis of the evolution of annually published documents, the productivity of Arab world countries, research institutions and authors, the quality of produced researches and collaboration figures. This effort will lead to collect a systematic data with an aim to bring up deep insights into Arab world research activities in groundwater. This study was restricted to 1417 documents extracted from Scopus database, having affiliation addresses belonging to the Arab world, and bearing article titles with terms related to groundwater. Therefore,

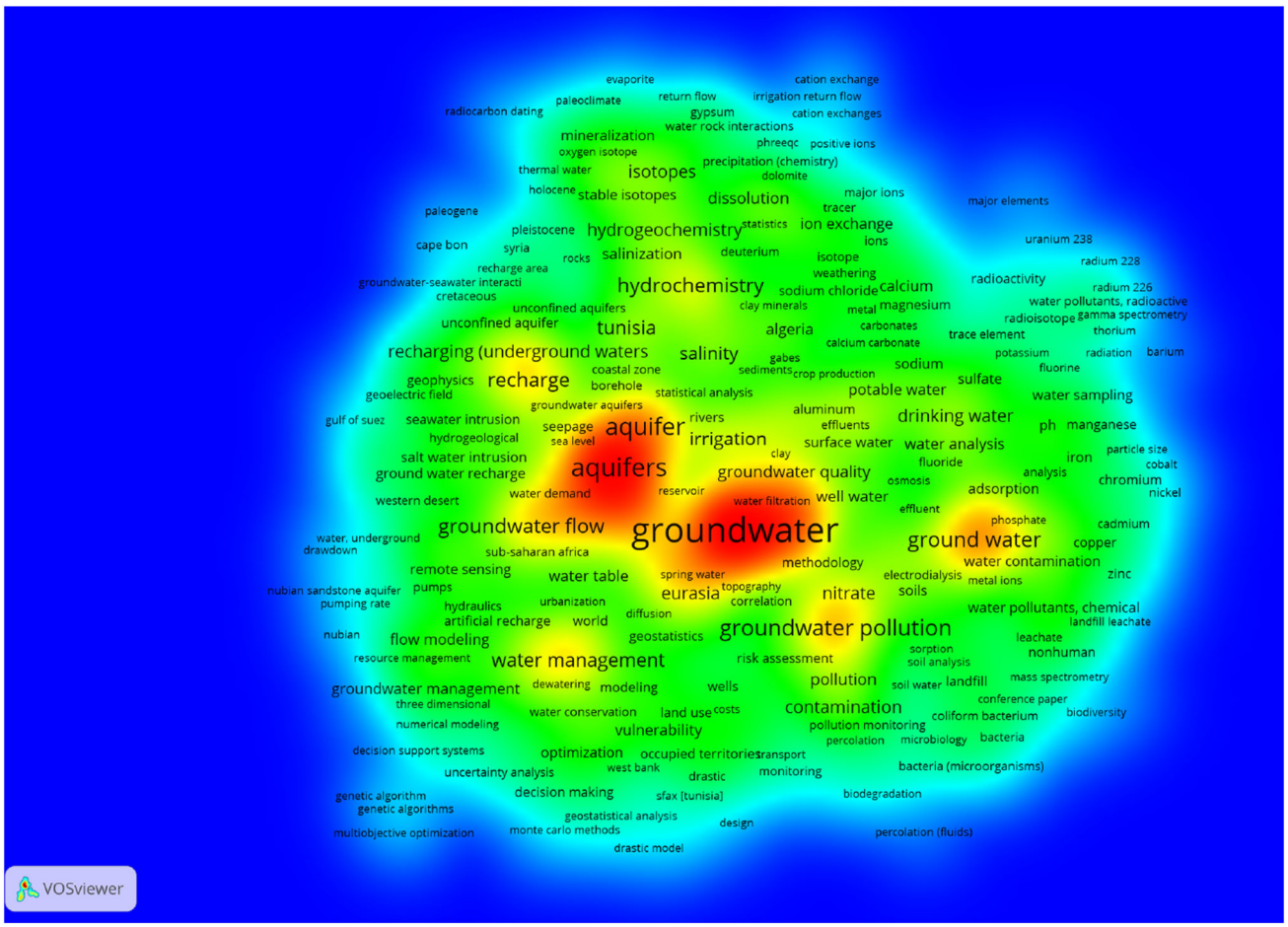

Fig. 2 Density visualization map of all keyword co-occurrence analysis related to groundwater research in Arab world with a threshold of five as a minimum number of occurrences of a keyword

it is difficult to consider this number of documents as a representative of groundwater literature covered by other index databases such as Science Citation Index (SCI) or Google Scholar. However, Scopus database covers a wider journals range and sustains as one of the best available database in tracking and analyzing citations and in comparing citations of different research teams and institutions (De Granda-Orive et al. 2011).

To the best of our knowledge, this article is the first of its kind that tackled the issue of analyzing groundwater–based research from Arab world taking into consideration both quantitative and qualitative bibliometric performance indicators. Research indicators showed that the research productivity in the field of groundwater at Arab world level began very modestly and relatively late compared to the initiation of research activities in this filed at global level. The first document as found in Scopus database was in 1889, entitled: "Disinfection of springs, and number of germs in ground-water", and it was published in Science (Science 1889), while in case of Arab world and as mentioned previously, the first article in groundwater context was in 1957. This indicates the depth of the gap between Arab world and the others in terms of paying attention to scientific research with the beginning of twentieth century. Being aware of the fact that most Arab countries were under colonization from the mid-nineteenth century until the mid-twentieth century, and most of the states were under-development (Yousef 2004). The annual number of published documents in the past six decades (1957–2015) pointed out that research productivity was low in the first four decades; a remarkable increase in the second half of 1990's, and a promising jump in the subsequent decade, with a peak of publications in 2014. These figures are compatible with the increase in research productivity and the encouraging trends of citation indicators that have been observed for this region during the last decade (Adams et al. 2011).

Investigation on the language of published documents from Arab world showed that English language was the prevalent. The use of English as an international language of science is by now well documented (Tardy 2004), and nearly 85% of all research output and technological

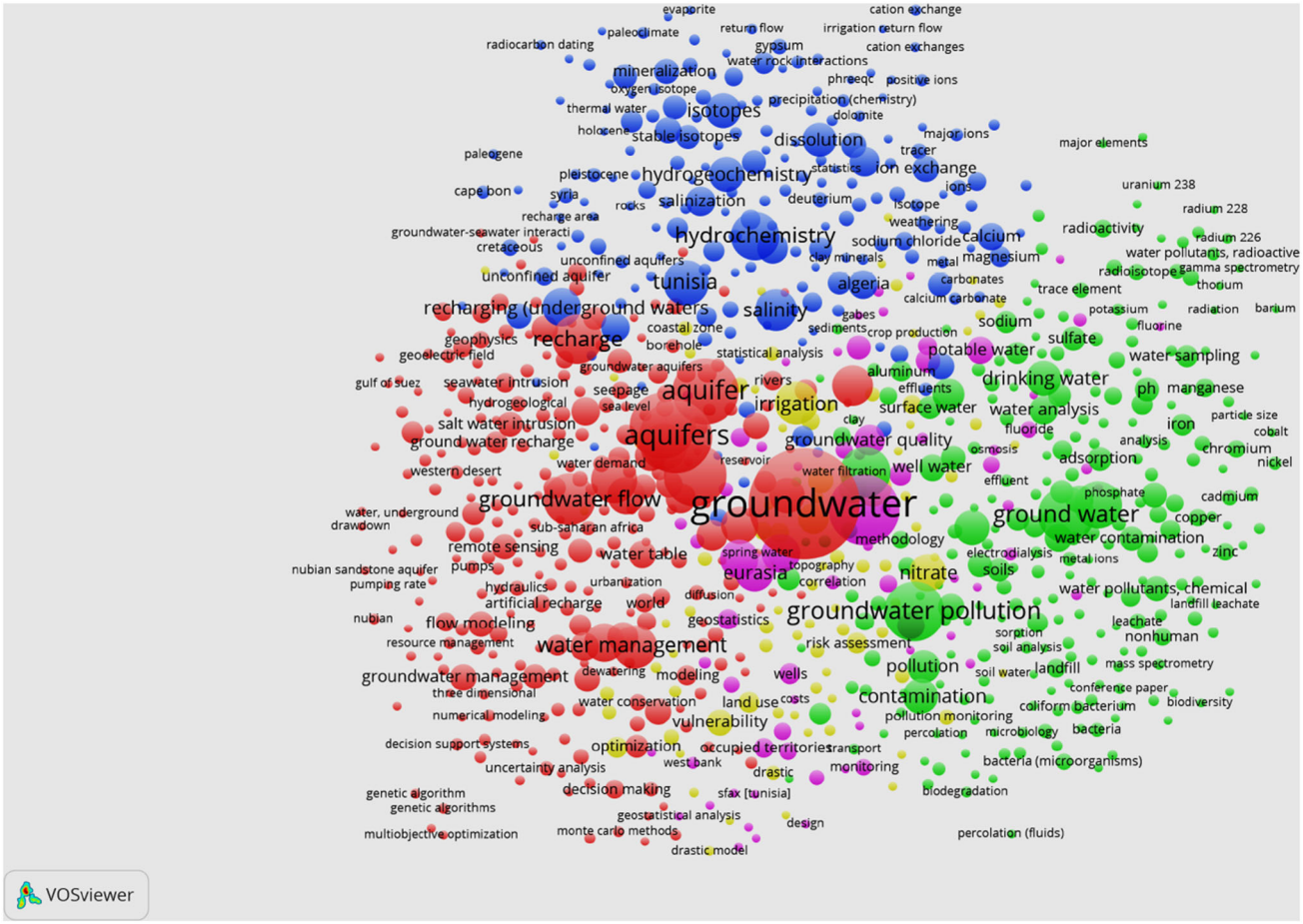

Fig. 3 Network visualization map and cluster density of all keyword co-occurrence analysis related to groundwater research in Arab world with a threshold of five as a minimum number of occurrences of a keyword

information in the world today are written and/or abstracted in English (Ammon 2001). Since English language is widely accepted as the language of science and technology, Arab researchers tend to use it to gain international credibility (Atwell et al. 2009). The Arab League Educational, Social and Cultural Organization conducted an initiative to run workshops where cutting-edge science and research are reported in Arabic, as a result, the proceedings begin to be inaccessible to most of English-speaking community (Atwell et al. 2009).

The bibliometric performance indicators showed non-specific pattern shared by all Arab countries in terms of research productivity, qualitative indicators, and collaborations figures and trends with other countries. Egypt, Saudi Arabia, Tunisia, Morocco Jordan and Algeria have shown a distinguish research productivity compared with other Arab states with evident superiority of Egypt and Saudi Arabia. Global research report by Adams et al. (2011) indicated that, Egypt, Saudi Arabia and Jordan have increased world share by around one third during the period from 2000 to 2009. This study concluded that some nations from the Arab region, such as Egypt, Jordan and Saudi Arabia are relatively frequent research collaborators with around 40% of their domestic output having one or more co-authors from another country (Adams et al. 2011). In case of Egypt, its population size is a vital factor among other factors in increasing its overall contribution since the research productivity of any country relies on the population size, socio-economic factors and the overall scientific activities (Miró et al. 2009). Egypt is second on its continent, after South Africa, in scientific production (Waast and Rossi 2010). Furthermore, it has a pioneer institution: National Water Research Center which occupies the ninth position in the list of most productive institutions in groundwater research at Arab world level. This research center is the largest one in the Middle East in science and technology which serves national, regional and international cooperation including technology transfer (Lorenzo 2010). The majority of water-related research in Egypt is carried out by this center which showed relatively high levels of influence in the water sector in Egypt. The involvement of universities is covered by the ministry's

Table 4 List of top 20 journals in which groundwater-related documents from Arab world were published

SCR[a]	Journal	No. of documents (%)	IF (2015)[b]
1st	Arabian Journal of Geosciences	99 (7.0)	1.224[c]
2nd	Environmental Earth Sciences	69 (4.9)	1.765[b]
3rd	Environmental Geology	50 (3.5)	1.078[c]
4th	Hydrogeology Journal	37 (2.6)	2.028
4th	Water Resources Management	37 (2.6)	2.437
6th	Journal of Hydrology	35 (2.5)	3.043
7th	Desalination	33 (2.3)	4.412
8th	Journal of African Earth Sciences	31 (2.2)	1.326
9th	Desalination and Water Treatment	28 (2.0)	1.272
10th	Environmental Monitoring and Assessment	25 (1.8)	1.633
11th	Hydrological Sciences Journal	23 (1.6)	2.182
12th	Hydrological Processes	20 (1.4)	2.768
13th	Journal of Environmental Hydrology	17 (1.2)	NA
14th	Arabian Journal for Science and Engineering	16 (1.1)	0.728
15th	International Journal of Water Resources Development	15 (1.1)	1.463
15th	Irrigation and Drainage	15 (1.1)	0.565
17th	Ground Water	14 (1.0)	NA
17th	Wit Transactions on Ecology and The Environment	14 (1.0)	NA
19th	Revue Des Sciences De L Eau	13 (0.9)	NA
20th	Journal of Materials and Environmental Science	11 (0.8)	NA

SCR standard competition ranking, *NA* not available, *IF* impact factor

[a] Equal journals have the same ranking number, and then a gap is left in the ranking numbers

[b] The impact factor was reported according to Institute for Scientific Information (ISI) journal citation reports (JCR) 2015

[c] The impact factor of the journal was extracted from the journal homepage for the year 2014 as it is not available in 2015 JCR release

[d] Coverage discontinued in Scopus since 2009 and continued as Environmental Earth Sciences

own research institutions housed in this center, and the groundwater sector showed high influence in each functional area of research (USAID 2010). Saudi Arabia was the most collaborated country with Egypt and vice versa. This is related to the solid research partnerships between the two countries where the joint research on annual bases has risen tenfold in the last decade and is accelerating (Adams 2012).

Saudi Arabia topped the second position in terms of scientific productivity at Arab world level. This country has witnessed during the last two decades a comprehensive development in all sectors together with increase in population and living standards (FAO 2009). It has a long-term strategy to set up a science base through localizing the best foreign capabilities and innovative research and development firms in knowledge villages running by foundations such as King Abdul-Aziz city for science and technology (Waast 2010). Since a significant portion of water demand in Saudi Arabia is met from groundwater, this increases the attention to be given to research related to quantity, quality and monitoring of groundwater sources (Bob et al. 2016). In the list of top productive institutions, King Abdul-Aziz University from Saudi Arabia occupies the first position. As in case of Egypt, six institutions from Saudi Arabia were in the list of most productive institutions in groundwater research. Saudi Arabia showed high rates of collaboration with other countries which is an outcome of the fact that Saudi Arabia had bigger pool of international scholars than most other countries (Shin et al. 2012). Tunisia is one of the most water stressed regions in Northern Africa and its groundwater resources are vulnerable to deterioration in terms of quantity and quality, and as a result, it has continuously developed management tools updated with changes in groundwater (Frija et al. 2015). One of its pioneer institutions, Ecole Nationale d'Ingenieurs de Sfax, occupied the second position in the list of most productive institutions. The case is same for Morocco, which is a highly water stressed nation, and under this pressure, the scientific community motivated to recognize adequate management strategies to protect groundwater sources from contamination and overexploitation.

The collaboration figures in groundwater research showed high rates of collaboration between Arab world and countries from Western Europe, mainly France, followed

Table 5 Ranking of top 20 most cited articles in Scopus database in fields of research originated from Arab world and related to groundwater

SCR[a]	Name of authors and year of publication	Title	Journal Name	Type of document	Times Cited
1st	Bakalowicz, M., 2005	Karst groundwater: A challenge for new resources	Hydrogeology Journal	Article	259
2nd	Storey, R.G. et al., 2003	Factors controlling riffle-scale hyporheic exchange flows and their seasonal changes in a gaining stream: A three-dimensional groundwater flow model	Water Resources Research	Article	154
3rd	Edmunds, W.M. et al., 2003	Groundwater evolution in the Continental Intercalaire aquifer of southern Algeria and Tunisia: Trace element and isotopic indicators	Applied Geochemistry	Article	137
4th	Al-Adamat, R.A.N. et al., 2003	Groundwater vulnerability and risk mapping for the Basaltic aquifer of the Azraq basin of Jordan using GIS, Remote sensing and DRASTIC	Applied Geography	Article	136
5th	Almasri, M.N. and Kaluarachchi, J.J., 2004	Assessment and management of long-term nitrate pollution of ground water in agriculture-dominated watersheds	Journal of Hydrology	Article	102
6th	Almasri, M.N. and Kaluarachchi, J.J., 2005	Modular neural networks to predict the nitrate distribution in ground water using the on-ground nitrogen loading and recharge data	Environmental Modeling and Software	Article	83
7th	Almasri, M.N. and Kaluarachchi, J.J., 2007	Modeling nitrate contamination of groundwater in agricultural watersheds	Journal of Hydrology	Article	75
8th	Tahaikt, M. et al., 2007	Fluoride removal from groundwater by nanofiltration	Desalination	Article	74
9th	Garmes, H. et al., 2002	Defluoridation of groundwater by a hybrid process combining adsorption and Donnan dialysis	Desalination	Article	69
10th	Sturchio, N.C. et al., 2004	One million year old groundwater in the Sahara revealed by krypton-81 and chlorine-36	Geophysical Research Letters	Article	67
11th	Abu-Rukah, Y. and Al-Kofahi, O., 2001	The assessment of the effect of landfill leachate on ground-water quality - A case study. El-Akader landfill site - North Jordan	Journal of Arid Environments	Article	66
12th	Forkutsa, I. et al., 2009	Modeling irrigated cotton with shallow groundwater in the Aral Sea Basin of Uzbekistan: II. Soil salinity dynamics	Irrigation Science	Article	60
12th	Elmidaoui, A. et al., 2001	Pollution of nitrate in Moroccan ground water: Removal by electrodialysis	Desalination	Article	60
14th	Harari, Z., 1996	Ground-penetrating radar (GPR) for imaging stratigraphic features and groundwater in sand dunes	Journal of Applied Geophysics	Article	57
15th	El Khalil, H. et al., 2008	Heavy metal contamination from mining sites in South Morocco: Monitoring metal content and toxicity of soil runoff and groundwater	Environmental Monitoring and Assessment	Conference Paper	56
15th	Subyani, A.M., 2004	Use of chloride-mass balance and environmental isotopes for evaluation of groundwater recharge in the alluvial aquifer, Wadi Tharad, western Saudi Arabia	Environmental Geology	Article	56
17th	Walha, K. et al., 2007	Brackish groundwater treatment by nanofiltration, reverse osmosis and electrodialysis in Tunisia: performance and cost comparison	Desalination	Article	55
17th	Ebraheem, A.-A.M. et al. 1997	Geoelectrical and hydrogeochemical studies for delineating ground-water contamination due to salt-water intrusion in the northern part of the Nile Delta, Egypt	Ground Water	Article	55
19th	Almasri, M.N., 2007	Nitrate contamination of groundwater: A conceptual management framework	Environmental Impact Assessment Review	Article	54
19th	Afonso, M.D. et al., 2004	Brackish groundwater treatment by reverse osmosis in Jordan	Desalination	Article	54

SCR standard competition ranking

[a] Equal articles have the same ranking number, and then a gap is left in the ranking numbers

Table 6 Ranking of top 20 most productive institutions in fields of research related to groundwater during the period of the study

SCR[a]	Name of Institution	No. of documents (%)
1st	King Abdulaziz University, Saudi Arabia	66 (4.7)
2nd	Ecole Nationale d'Ingenieurs de Sfax, Tunisia	64 (4.5)
3rd	King Saud University, Saudi Arabia	56 (4.0)
4th	Sultan Qaboos University, Oman	42 (3.0)
5th	Universite Cadi Ayyad, Morocco	41 (2.9)
5th	Kuwait Institute for Scientific Research, Kuwaiat	41 (2.9)
7th	United Arab Emirates University, United Arab Emirates	37 (2.6)
7th	The University of Jordan, Jordan	37 (2.6)
9th	National Water Research Center, Egypt	36 (2.5)
10th	King Fahd University of Petroleum and Minerals, Saudi Arabia	29 (2.0)
10th	Universite Badji Mokhtar, Algeria	29 (2.0)
12th	Atomic Energy Authority of Egypt, Egypt	26 (1.8)
12th	King Abdulaziz City for Science and Technology, Saudi Arabia	26 (1.8)
14th	Desert Research Center, Cairo, Egypt	24 (1.7)
15th	National Research Institute of Astronomy and Geophysics, Cairo, Egypt	21 (1.5)
16th	Ain Shams University, Egypt	20 (1.4)
17th	King Saud University College of Science, Saudi Arabia	19 (1.3)
17th	Mansoura University, Egypt	19 (1.3)
17th	Mohammed V University in Rabat, Morocco	19 (1.3)
17th	Hashemite University, Jordan	19 (1.3)
17th	King Abdullah University of Science and Technology, Saudi Arabia	19 (1.3)

SCR standard competition ranking

[a] Equal institutions have the same ranking number, and then a gap is left in the ranking numbers

by countries from Northern America, mainly United States. France sits in the foreground in terms of international collaboration between Arab countries and non-Arab countries. This finding is a result of the significant contribution of three Maghrebin countries: Morocco, Tunisia, and Algeria in association with the strong international collaboration between the three countries and France. One hundred and seven documents is the outcome of collaboration between the three Maghrebin countries and France. It is affirmed that France is heavily engaged in research and associated with its former colonies in research collaborations (Harford 2015; Nature 2015). A study of international collaboration clusters in Africa conducted by Adams et al. (2014) showed that, the research axis between Egypt, Saudi Arabia and United States is an instructive example of new and changing collaboration patterns, and the number of papers co-authored between Egypt and the United States has grown but has remained around 10% of Egyptian output since 1995. Furthermore, the number of papers co-authored between Egypt and Saudi Arabia has been much smaller historically but reached 4% of Egypt's output in 2002 and exceeded 15% in 2011 (Adams et al. 2014). Regarding patterns of collaboration between Egypt and United States, the current study showed that 39 (12%) documents out of total published documents by Egypt resulted from international collaboration between Egypt and United States. Saudi Arabia occupies the first position in terms of collaboration with Egypt and this result is compatible with the finding of the study conducted by Adams (2012) who pointed out that the joint research between Egypt and Saudi Arabia has boosted during the last decade tenfold and is swiftly accelerating. The United States produces a low percentage of multi-national publications compared to its overall output in scientific research, but it remains a major producer of multi–national publications due to the large total output of contributions. It is playing an important role in networking international research collaboration (Gazni et al. 2012). Easier access to public financing, opportunities to attain higher productivity, and aspirations for greater prestige and visibility resulting from collaboration with renowned research groups are factors that attract increasing attention to international collaborations (Abramo et al. 2009).

The vast majority of published research from Arab world focused on evaluation of groundwater resources in the context of their quality and quantity, the mitigation measures, policies and management practices to eliminate the consequences of witnessed deterioration and the

Table 7 Ranking of top 20 most prolific authors who published in fields of research related to groundwater with their affiliations

SCR[a]	Author	No. of publications (%)[b]	Total publications of author[c]	Affiliation
1st	Zouari, K.	36 (2.54)	81	Ecole Nationale d'Ingenieurs de Sfax, Department of Geology, Sfax, Tunisia
2nd	Bouri, S.	16 (1.13)	43	ENI, Rome, Italy
3rd	Bouhlila, R.	15 (1.06)	42	University of Tunis, Laboratory of Modelling in Hydraulics and Environment (LMHE), Tunis, Tunisia
3rd	Salameh, E.	15 (1.06)	77	The University of Jordan, Faculty of Science, Amman, Jordan
5th	Bouchaou, L.	14 (0.99)	40	Universite Ibn Zohr, Applied Geology and Geo-Environment Laboratory, Agadir, Morocco
5th	Mukhopadhyay, A.	14 (0.99)	37	Kuwait Institute for Scientific Research, Water Research Center, Safat, Kuwait
5th	Tarhouni, J.	14 (0.99)	50	University of Carthage, Tunis, Tunisia
8th	Awad, M.A.	13 (0.92)	17	Zagazig University, Zagazig, Egypt
9th	Dhia, H.B.	12 (0.85)	34	Ecole Nationale d'Ingenieurs de Sfax, Sfax, Tunisia
9th	Gueddari, M.	12 (0.85)	39	University of Tunis, Department of Geology, Tunis, Tunisia
9th	Hussein, M.T.	12 (0.85)	29	King Saud University, Riyadh, Saudi Arabia
12th	Al-Ruwaih, F.M.	11 (0.78)	43	University of Kuwait, Department of Earth and Environmental Sciences, Safat, Kuwait
12th	Chkir, N.	11 (0.78)	25	Faculty of Letters and Humanities, Department of Geography, Sfa, Tunisia
12th	Hamza, M.S.	11 (0.78)	24	Marine Biology Research Centre (MBRC), Tripoli, Libyan Arab Jamahiriya
12th	Batayneh, A.	11 (0.78)	55	Yarmouk University, Department of Earth and Environmental Sciences, Irbid, Jordan
12th	Kacimov, A.R.	11 (0.78)	123	Sultan Qaboos University, Department of Soils, Muscat, Oman
12th	Sherif, M.M.	11 (0.78)	47	United Arab Emirates University, Department of Civil & Environmental Engineering, Al Ain, United Arab Emirates
18th	Al-Senafy, M.	10 (0.71)	23	Kuwait Institute for Scientific Research, Water Research Center, Safat, Kuwait
18th	Ben Dhia, H.	10 (0.71)	45	Ecole Nationale d'Ingenieurs de Sfax, Sfax, Tunisia
18th	Djabri, L.	10 (0.71)	26	Universite Badji Mokhtar - Annaba, Water Resources and Sustainable Development Laboratory, Annaba, Algeria
18th	Hafsi, M.	10 (0.71)	19	Office National de l'Eau Potable, Agdal Rabat, Morocco
18th	Zouhri, L.	10 (0.71)	41	Institut Polytechnique LaSalle Beauvais, Beauvais, France

SCR standard competition ranking

[a] Equal authors have the same ranking number, and then a gap is left in the ranking numbers

[b] Percentage of publications for each author out of the total number of documents

[c] As recorded in Scopus database

employing of technological innovations in this regard. Employing advanced tools such as remote sensing, geographic information systems, radar data and geo-statistics tools for groundwater mapping, pollution assessment and simulation of groundwater management options in arid environments were common in research (El Alfy et al. 2015; Elbeih 2014; Loni et al. 2015; Madani and Niyazi 2015; Makkawi 2015; Mallick et al. 2015; Schulz et al. 2015; Sefelnasr et al. 2015; Siebert et al. 2014). Examining the issue of increasing groundwater salinity was of significant concern (Farid et al. 2015; Fehdi et al. 2011; Mhamdi et al. 2015; Salameh et al. 2014). The irrigation practices in association with groundwater management are heavily investigated (Alaya et al. 2014; Frija et al. 2015; Zouahri et al. 2015). Topics of concern were related to groundwater recharge (Regnery et al. 2015; Zaidi et al. 2015) and employing multi criteria decision analysis techniques and multi-objective optimization tools for integrated groundwater management (Gdoura et al. 2015; Nouiri et al. 2015).

This study is without limitations, as it is common in bibliometric studies. While the findings of this study give a deep insight into research activities related to groundwater in Arab world, there were some exceptions. In particular, this study adopted only Scopus database criteria for including groundwater-related terms. Documents published

in non-Scopus-cited journals were not considered, although they might have contribution to research productivity. Furthermore, this study is restricted to terms related to groundwater in the article titles only without diving into texts and abstracts. This means that this analysis does not represent completely all groundwater-based research activities. Despite these limitations, this study provides a good representative frame about the current status of groundwater research in the Arab world.

Conclusions

This study shows remarkable evidence that the research productivity in fields related to groundwater research at Arab world level has reasonably increased in rapid manner during the last period. This renaissance is associated with the global revolution in the scientific research and the developments of most socio-economic sectors in Arab world. A good boost in the amount of published research from this region has been witnessed and the quality of research performance indicators is promising. An obvious difference in terms of research output, indicators of research quality and collaboration figures among Arab world countries were documented. An urgent action to bridge the gaps in groundwater-based research between Arab world and other nations are required. Promotion of the effective evaluation tools for better groundwater management and identifying the risks arising from depletion of groundwater resources and contamination are substantial keys to success in this regard. As Egypt and Saudi Arabia are the most influential and leading countries in scientific research among the Arab world, the two countries should address the challenges that are hindering the progress of scientific research and should work to shape in collaboration with other Arab countries the required plans and future investments in technological innovations which have major potentials to mitigate the groundwater quality and quantity deteriorations. This study provides a prolific informative analysis for scholars in disciplines related to groundwater management and concerned people engaged in evaluative bibliometric.

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