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Activity Index (AI) and extent of collaboration: a case study of rainwater harvesting literature with a scientometric overview

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Activity Index (AI) and extend of collaboration: a case study of rainwater harvesting literature with a scientometric overview

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Abstract
Rainwater harvesting research is being conducted in much wider perspectives from agriculture to using in house toilets. The study has assessed the research activity by different countries with the help of Activity Index (AI) and the collaboration and its impact. The SCOPUS publication records are made use of for the analysis of RWH research activities. The quality of the publications is analysed in terms of citations received to the papers and Spain has come on the top having 42 citations per paper. Cross-field relative activity in rainwater harvesting research is measured and it was interesting to note that among the leading countries conducting RWH research, a few developed countries are below world average of RWH activity. Out of the 141 countries which have at least one publication on RWH, 132 (94%) have at least one paper written in collaboration with other countries. US is the collaboration hub of many countries and the strength of collaboration of India, China, UK, Brazil is noteworthy. It was also found that there is a positive correlation between the collaboration strength and impact of papers. The results are relevant to know the relative of strength of different countries in RWH as well as boosting the collaboration among countries and researcher mobility.

Keywords: Rainwater Harvesting; Activity Index; Country Collaboration; Collaborated Research; Scientometric Analysis

Introduction

As much as 97% of the world's total water is in oceans, 2% is locked in the polar caps and only the balance 1% is fresh water. Recently water resources are being degraded because of many reasons like climate change, population growth, land use, urban expansion, demand from different productive sectors, hydro-political scenarios, overexploitation, rainwater scarcity, over evaporation, increase in temperatures etc. (Liu et al. 2017; Fiaz et al. 2018). Technologies are on to develop dams, reservoirs, canals, irrigation tanks etc. but, it has become incessant practice to supplement water through roof top rain water harvesting structures to provide safe drinking water to the community because of many reasons (Gupta et al. 2015). Irrespective of developed or developing or underdeveloped countries where scarcity of water is a major issue, rainwater harvesting (RWH) systems are found as the sustainable alternative to the traditional water reservoirs. Qadir et al. (2007) defined rainwater harvesting as the management, control, and use of rainwater in situ or its storage for future use. Rainwater harvesting comprises all of the methods by which rainwater and run-off are managed effectively for different uses (Baguma and Loiskandl 2010; Biazin et al. 2012). Rainwater harvesting systems range from simple rain barrels to more elaborate structures with pumps, tanks, and purification systems.

Rainwater harvesting has become the topic of study for many from the angle of drinking water demand. Within a context of scarce water resources for agriculture, rainwater harvesting constitutes a promising alternative that has been also studied by different disciplines in recent years (Velasco-Muñoz et al. 2019).

It can be observed from a cursory glance through the published documents on RHW that researchers from different areas like environmental sciences, health professions, geology, civil engineering, agriculture, information technology, social sciences, medicine, business, management, economics, toxicology etc. have worked on different realms of RWH (Amin et al. 2013; Gupta 1994; Jebamalar et al. 2012). Some of them studied about the barriers to implement RWH systems, its potency, and projections (Sivanap 2017; Tucunan et al. 2018). The studies also include large scale RWH systems to domestic implementation. Domestic implementation is mainly towards irrigate landscaping, flush toilets, wash cars, or launder clothes etc. There are studies on socio-economic factors of implementing RWH systems as well as marketing of RWH practices and methods (Pacey and Cullis 1986; Ajith Kumara and Wickramasinghe 2004; Gera 1999; Ghimire et al. 2012; Gupta and Bhattacharjee 2005; Jebamalar et al. 2013; Karthick et al. 2019; Musz-Pomorska et al. 2020).

Many recent studies involved methods and application of technologies infused with modern technologies, information technology, artificial intelligence, internet of things (IoT) etc. (Liaw and Tsai 2004; Mahmood et al. 2020; Mohammad et al. 2017a, 2017b; Sepehri et al. 2018; Willy and Kuhn 2016). Site suitability for large scale RWH is another area of studies of surveys in nature (Nageswara Rao 2017; Nimje and Wayal 2019). Few studies discussed RWH in term of food security and regeneration of ground water (Nachshon et al. 2016; Otunchieva 2016; Pines and Glucksberg 2010; Singh et al. 2019).

Schubert and Braun (1986) have discussed about building some kind of relative indicators which enable cross-field comparisons to assess the performance or impact through each published papers in a given field. Activity Index (AI) was one of the relative indicators first proposed by Frame (1977) and was used by Bujdosó and Braun (1983) and Braun et al. (1986) where the indicator is characterized by the relative research effort a country devotes to a given field. The definition is as follows:

$$\mathrm{AI} = \frac{\text{The country's share in world's publication output in the given field}}{\text{The country's share in world's publication output in all science fields}}$$

Or equivalently

$$\mathrm{AI} = \frac{\text{The given field's share in the country's publication output}}{\text{The given field's share in world's publication output}}$$

AI = 1 indicates the country's research effort corresponds precisely to that of world average in the field; AI > 1 reflects higher than the average, and AI < 1 lower than the average effort dedicated to the field under study. Generally, no country can possess high AI in all science fields. The definition also says that the average, in certain sense, of the AI's over the different fields must be equal to one for each single country. The present paper made an effort to evaluate the AI in different time periods of countries involved in RWH research and make a comparative statement.

Again, it may be very interesting to analyse the relationships among researchers in the field in terms of inter-national collaboration trends. Collaboration pattern of researchers are studied in different fields like talent management research (Gallardo-Gallardo et al. 2017); educational research (Munoz et al. 2016); scientometrics (Chen et al. 2013; Erfanmanesh et al. 2012; Goldenberg et al. 2010; Sagar et al. 2010; Kademani et al. 2011a, 2011b; Prakasan et al. 2014); influenza virus vaccine field (Liu et al. 2018; adolescent myopia prevention and control (Wu et al. 2019); methane hydrate research (Lu and Ma 2017); soil science (Minasny et al. 2020); sustainable mining (Bemke-Świtilnik e al. 2020); biotechnology (Egelie et al. 2019); disaster risk management (Tavakoli Taba et al. 2019); nanoscience and nanotechnology (Mohan et al. 2010); materials chemistry (Mohan et al. 2003; Walke and Dhawan 2007). The present study has also made an attempt to answer the extent, nature and quality of collaborated publications on RWH

which may enable to frame national level policies on collaboration and encourage internationally collaborated works.

Objectives

The publication profiles in the field of RWH provide a lot of indications regarding the past, present and future of RWH research. The present papers have taken a few parameters for the present study. The broad objective of the study is to assess the RWH research in terms of country strengths and author collaborations. The specific objectives are as follows:

1) Present the chronology of published papers on RWH
2) Identify leading countries involved in RHW research and briefing other attributes of the authors and papers
3) Compare the overall Activity Index (AI) and AI in different time periods of the leading countries
4) Exhibit the collaboration pattern of the leading countries
5) Analyse quality of the collaborated papers in terms of citations per paper

Materials and Methods

The study is based on publication records related to rainwater harvesting appeared in SCOPUS, Elsevier's abstract and citation database research published during 1975-2019. This study was limited to article and review types of documents only. The following is the query run in SCOPUS for retrieving records pertaining to RWH.

(TITLE-ABS-KEY (rain AND harvesting) AND DOCTYPE (ar OR re) AND PUBYEAR > 1974 AND PUBYEAR < 2020) OR (TITLE-ABS-KEY (rain AND harvest) AND DOCTYPE (ar OR re) AND PUBYEAR > 1974 AND PUBYEAR < 2020) OR ((TITLE-ABS-KEY (rain AND water AND harvest) AND DOCTYPE (ar OR re) AND PUBYEAR > 1974 AND PUBYEAR < 2020) OR (TITLE-ABS-KEY (rain AND water AND harvesting) AND DOCTYPE (ar OR re) AND PUBYEAR > 1974 AND PUBYEAR < 2020) AND (LIMIT-TO (PUBSTAGE , "final"))

The records were then transferred to MS-Excel, spreadsheet application for further analysis and full counting of occurrence of parameters was done instead of taking the fractional counting as is being done by some scientometricians. VOSviewer, software tool for constructing and visualizing bibliometric networks is made use of for drawing graphs.

Results and Discussions

The SCOPUS search resulted into 3747 publication records related to rainwater harvesting and these records were analysed as per the objectives of the study. The results are discussed in the following sessions:

Growth in publications and leading countries

The growth in number of publications in a field varies based on many factors viz. the research infrastructure, financial conditions, support from the higher ups etc. This particular study has observed a linear growth in number of RWH related publications as shown in Figure 1 where the growth is shown in different span of 5 years from 1975 onwards. An average growth of 65% research articles is observed from the first span to the last and it will be interesting to study contribution of individual countries in volume of growth of RWH publications.

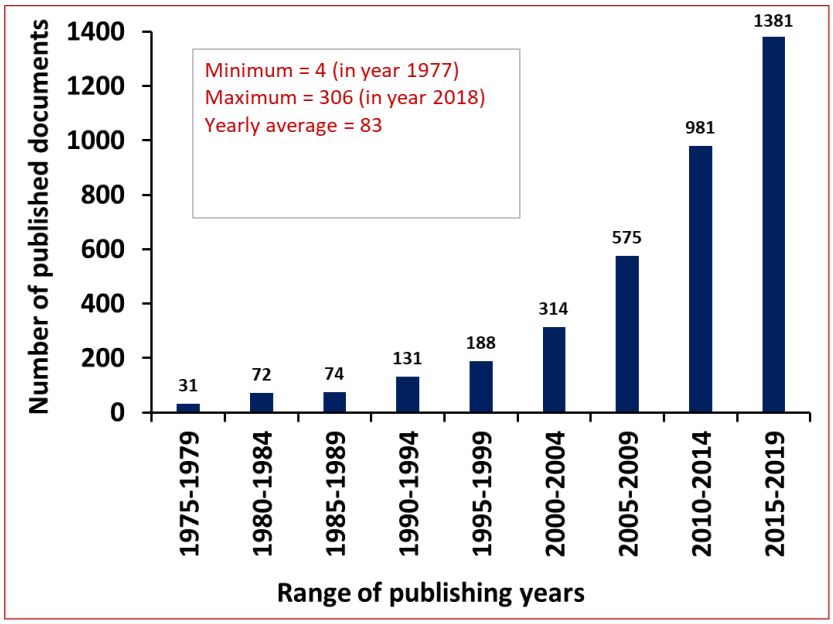

Fig 1 Chronology of number of published documents on RWH in five year periods as per SCOPUS Database

The countries in the affiliation of the authors are analysed and it was found that 141 countries have at least one paper in the area. The total number of RWH related publications by leading 13 countries (which have at least 100 publications) constitutes about 73% of total publications. The countries are listed in descending order of their number of publications in Table 1. The table also contains the total span of research and citations per paper of the countries in order to show the time duration the country is involved in RWH research and the quality of the research in terms of citations respectively. When the Table is observed closely, the figures of Spain indicate that it started RWH research very late and within a span of 27 years could publish 129 quality papers (citations per paper = 42) with an yearly average of 5 papers. In terms of yearly number of papers, China is equal to US even though China's span of research is almost half of US.

Table 1 Leading countries (> 100 publications) pursuing RWH research with span of research, average papers per year and citations per paper as per SCOPUS Database (1975-2019)

Country	No. of papers	FPY*	LPY*	Span of research (in years)	Average papers per year	Citations per paper
United States	746	1975	2019	45	17	33
China	419	1996	2019	24	17	18
India	361	1979	2019	41	9	12
Australia	311	1979	2019	41	8	27
United Kingdom	215	1978	2019	42	5	30
Brazil	197	1982	2019	38	5	17
Germany	141	1975	2019	45	3	41
South Africa	138	1976	2019	44	3	17
Canada	135	1982	2019	38	4	29
Spain	129	1993	2019	27	5	42
France	122	1986	2019	34	4	40
Netherlands	114	1975	2019	45	3	27
Japan	106	1978	2019	42	3	21

*FPY = Year of first published paper; *LPY= Year of last published paper

The affiliations of authors are analysed and the highly productive institutions (> 30 publications) are listed in Table 2. The main mandate of majority of the institutes observed are agriculture indicative of the research organisations' focus on usage of rainwater for agricultural purposes.

Table 2 Active institutes involved in RWH research as per SCOPUS Database (1975-2019)

SN	Organisation	No. of Articles
1	US Department of Agriculture, United States	114
2	USDA Agricultural Research Service, United States	103
3	Chinese Academy of Sciences, Beijing, China	98
4	Northwest Agriculture and Forestry University, Yangling, China	81
5	Commonwealth Scientific and Industrial Research Organization - CSIRO, Australia	73
6	Wageningen University, Wageningen, Netherlands	61
7	Indian Council of Agricultural Research - ICAR, India	46
8	North Carolina State University, Raleigh, United States	41
9	CSIRO Land and Water, Australia	40
10	Seoul National University, Seoul, South Korea	39
11	University of Florida, Gainesville, United States	39
12	Ministry of Agriculture, China	38
13	Empresa Brasileira de Pesquisa Agropecuária - Embrapa, Brazil	34
14	Ministry of Education, Beijing, China	34
15	Texas A&M University, College Station, United States	34
16	National Institute for Agricultural Research - INRA, Paris, France	31
17	University of Sao Paulo, Sao Paulo, Brazil	31
18	China Agricultural University, Beijing, China	30

The research articles published in journals reflect the systematic and thorough study of a single topic, often involving original research, experimentation, and surveys. The highly preferred journals for publication of rainwater harvesting research articles are listed in Table 3 with impact Factors. The quality of the published papers may also be judged based upon the Impact Factors of the journals in which the research articles are published and in this case, the average Impact Factor of the highly preferred journals is found as 3.1.

Table 3 Highly preferred journals for publication of RHW related research articles as per SCOPUS Database (1975-2019)

SN	Journal	No. of Articles	Impact Factor (2018)
1	*Agricultural Water Management*	129	3.182
2	*Water*	83	2.069
3	*Forest Ecology and Management*	66	3.169
4	*Science of the Total Environment*	66	4.610
5	*Water Science and Technology: Water Supply*	58	0.674
6	*Field Crops Research*	55	3.127
7	*PLoS ONE*	55	2.766
8	*Resources, Conservation and Recycling*	53	5.120
9	*Water Resources Management*	52	2.644
10	*Water Science and Technology*	52	1.247
11	*Journal of Cleaner Production*	44	5.651
12	*Journal of Hydrology*	43	3.727
13	*Transactions of Chinese Society of Agricultural Engineering*	43	3.805
14	*Physics and Chemistry of the Earth*	39	1.923
15	*Soil and Tillage Research*	38	3.824
16	*Journal of Environmental Management*	37	4.005
17	*Journal of Environmental Quality*	34	2.405
18	*Hydrological Processes*	31	3.181
19	*Environmental Monitoring and Assessment*	30	1.804

Activity Index (AI)

The study has calculated the Activity Index (AI) of only the 13 countries which have at least 100 publications in the field of RHW and presented in Figure 2. In case of South Africa, the Activity index is found relatively very high compared to other countries which indicates the country has given high priority for RWH research than any other area of research. It has been observed from the figure that the four

countries out of 13 have AI < 1 are all developed countries. Productivity and quality analysis of papers segregated as from developed, developing and under developed countries will give more clarity about the activity by the corresponding countries.

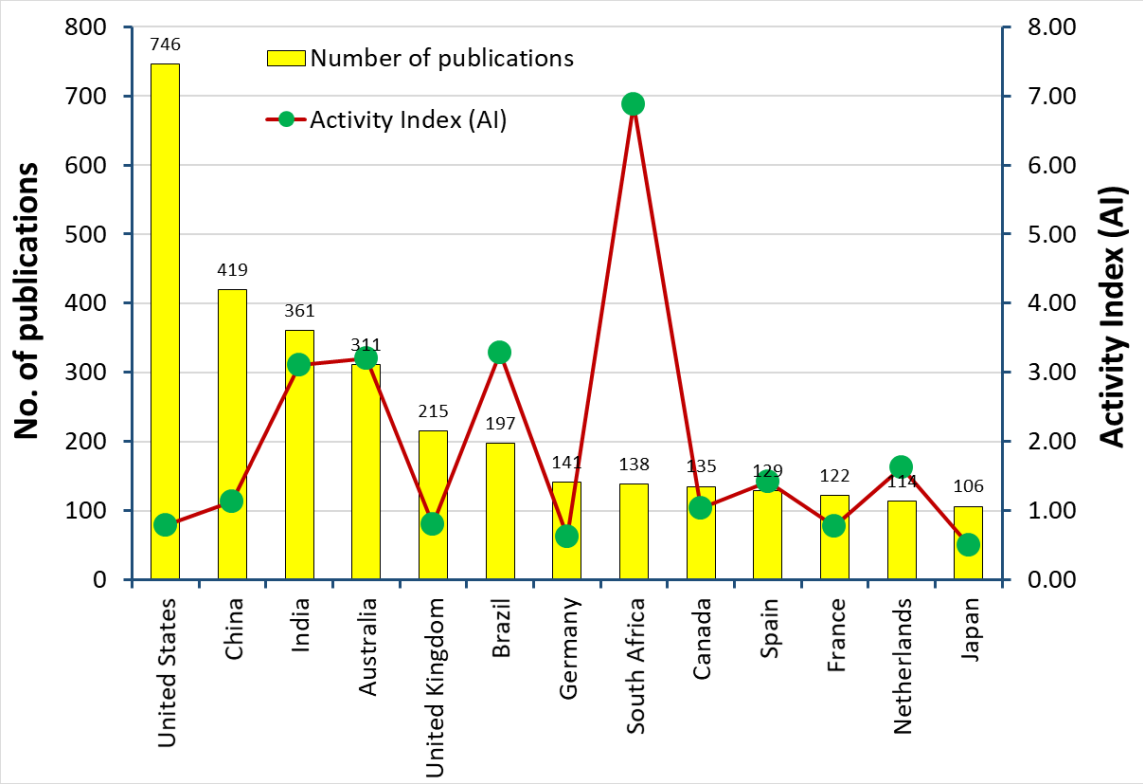

Fig 2 Activity Index of leading 13 countries which have at least 100 RWH related publications during 1975-2019 research as per SCOPUS Database

The publications have grouped into three groups of different year-blocks viz. published between 1975-89, 1990-2004 and 2005-2019. The trend of Activity is presented in Figure 3 in order to show the consistency in activity of the countries. It is very surprising to note observations on certain countries like China and Germany. China had hardly any activity during the first block of 1975-1989 where as Germany has a high AI in this period. The others reasons for the AI growth of Germany in the first block may be because of rapid growth of number of publications in other two blocks. Germany has published only 20,784 documents during 1975-1989 whereas publications during 1990-2004 and 2005-2019 are 11,75,070 and 24,34,583 respectively.

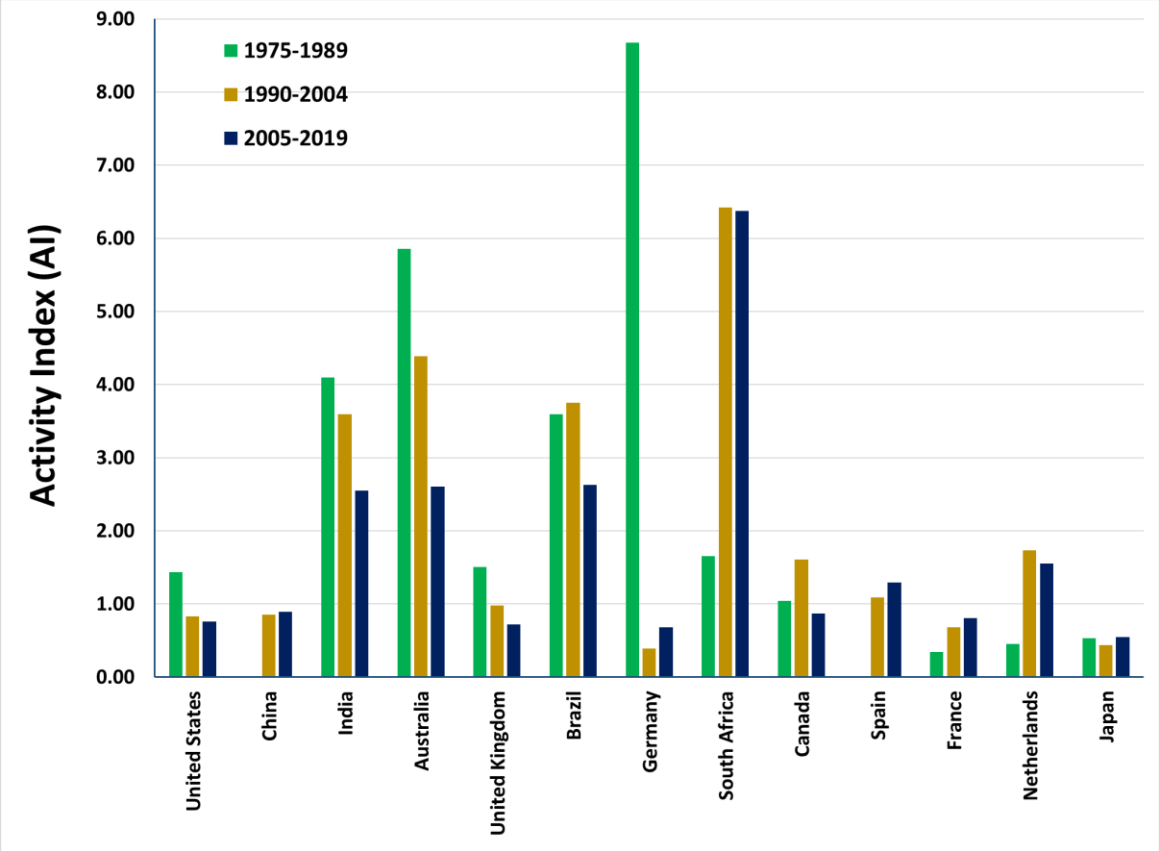

Fig 3 Activity Index of leading 13 countries which have at least 100 RWH related publications in three 15-year blocks as per SCOPUS Database

Country Collaboration

It is hypothesized that the more scientific and economic resources available in a country the greater the likelihood of collaboration and human resource mobility (Chinchilla-Rodríguez et al. 2018). Collaborative research is considered as an indicator of esteem and shared intellectual contributions. In another perspective, co-authorship networks offer a perspective on the ranks and positions of countries which provides an alternative to ranking shares of publications and citations (Leydesdorff et al. 2013). Many countries give due weightage to the collaborated works when individual or institute is assessed and now many governments has placed great emphasis on international cooperation (Wang et al. 2017). As it was mentioned above, among the total number of 141 countries involved in RWH research, 132 countries (94%) have at least one collaborated publication. The research collaboration is increasing linearly with an average rate of 21% in this field. Networks of the prominent collaborated countries involved in RWH is plotted and presented in Figure 4 where the strength of the connecting lines in the network shows the depth of collaboration of the countries. US has become the collaboration hub of many countries and collaboration strength of India, China, Australia, UK etc. is noteworthy.

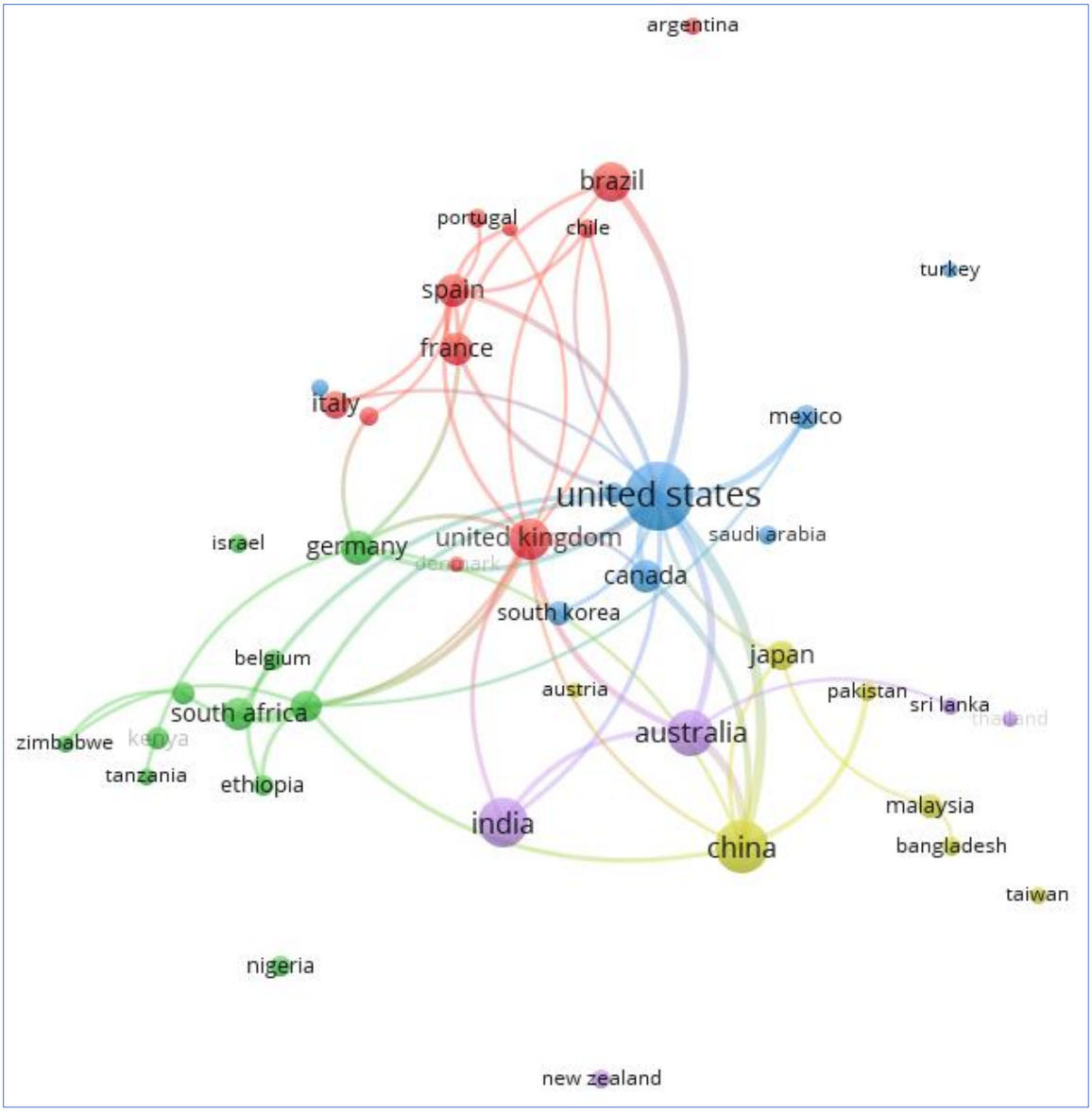

Fig 4 Collaboration observed among countries involved in RWH related research as evident from SCOPUS Database records (1975-2019)

Scholarly collaboration varies across disciplines in science, social science, arts and humanities and the effects of author collaboration on impact and quality of co-authored papers (Franceschet & Costantini 2010). The study analysed the relation between the collaboration intensity and the impact of the publications in terms of citations per paper and it is shown in Figure 5. There is a measured general positive association between the number of collaborated countries in the research papers and the citations per paper. The correlation is stronger for two papers written in collaboration of eight countries. The multi-country projects in the field may yield good quality papers.

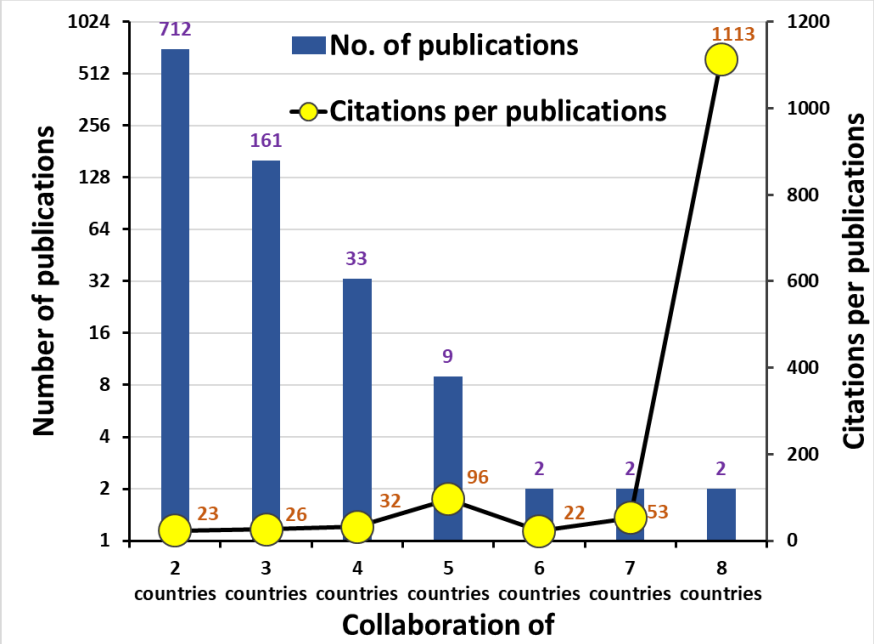

Fig 5 Number of collaborated countries v/s number of publications and citations per paper observed in RWH related publications as per SCOPUS Database (1975-2019)

Conclusion

Rainwater harvest research was in slow pace when earlier times especially the time period 1975-1990 is concerned for many of the countries. Assessing or making comparison of countries through the Activity Index is depend upon the size of the area. Bigger the area of research more the accuracy of the conclusions. The conclusions based on the Activity Index of many time periods may alter by the publication productivity of countries in different time periods. Comparison of Activity Index of countries within a subject area is another area of research. For example, the comparison of activity of various countries in 'RWH for agriculture' may be conducted. The extend of collaboration observed among countries involved in RWH research indicates that the societal commitment of the countries as well as the willingness to share the models and technology for RWH. The positive correlation between the extend of country collaborations and the impact of the collaborated papers will boost the researchers to have more collaboration and author mobility. The other corollary results of the study may give an insight to the administrators and policy makers in decision making.

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