

## Mapeando el desarrollo de la Ciencia Ciudadana en la última década: una visión global

### *Mapping the development of citizen science in the last decade: a global view perspective*

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#### Resumen

En la ciencia ciudadana, varios grupos participan en investigaciones con objetivos educativos, sociales o personales, beneficiando a todos los participantes. Como facilitador de la ciencia abierta, la ciencia ciudadana (CS) es accesible para desarrollar actividades científicas. Este estudio utiliza bibliometría para analizar las tendencias de investigación, identificando revistas, autores, palabras clave, liderazgo y colaboración en revistas de acceso abierto de Scopus durante la última década. Hasta el 6 de mayo de 2023, el análisis reveló 1,881 documentos sobre ciencia ciudadana de 2013-2022, con un crecimiento del 35.03%. Estados Unidos lideró con 629 documentos, seguido de Inglaterra con 441. PLOS One indexó la mayoría de los documentos, seguido de Citizen Science: Theory and Practice. Usando la ley de Bradford, se identificaron 24 revistas principales, indexando 621 documentos. King A.C. fue el autor más prolífico. El estudio encontró 9,860 palabras clave en cinco grupos, destacando el creciente interés en la ciencia ciudadana.

**Palabras clave:** Ciencia ciudadana, Ciencia abierta, Bibliometría, Scopus

#### Abstract

In citizen science, various groups engage in research for educational, social, or personal goals, benefiting all participants. As a facilitator of open science, citizen science (CS) is accessible for developing scientific activities. This study uses bibliometrics to analyze research trends, identifying journals, authors, keywords, leadership, and collaboration in open-access journals from Scopus over the last decade. By May 6, 2023, the analysis revealed 1,881 documents on citizen science from 2013-2022, with a 35.03% growth. The USA led with 629 documents, followed by England with 441. PLOS One indexed the most documents, followed by Citizen Science: Theory and Practice. Using Bradford's law, 24 core journals were identified, indexing 621 documents. King A.C. was the most prolific author. The study found 9,860 keywords in five clusters, highlighting the growing interest in citizen science.

**Keywords:** Citizen science, Open Science, Bibliometric, Scopus



## Introduction

Citizen science or demoscience, community-driven science or community-based research, is a movement considered an essential scientific strategy about scientific development supported by the community and society, which should be visible to the entire academy. Although several notions are similar to citizen science (Alfaro-Ponce et al., 2023), it can be defined as a method to incorporate and, occasionally, involve people who are not necessarily involved in the scientific research process, where the common goal is that anyone interested in advancing scientific knowledge can actively participate in various research phases, such as data collection, observation of natural events, and information processing (ECSA, 2015).

Citizen science mainly focuses on collaboration between professional researchers, research institutes, and non-specialists (people of all ages) who collect and evaluate data. In this regard, various investigations have questioned how citizen science contributes bidirectionally to citizen learning processes when they are not necessarily of an educational nature, as well as the influence on public policy or industry concerns. As a result, citizen science, with its central feature of high participation in data collection, has been positioned as an adequate foundation for open science, which is a classic scientific transformation agent (Frigerio et al., 2021).

Demoscience has allowed the collection of data in numerous sizes according to the different research objectives of the interest groups that address unprecedented research topics in recent decades (Klinger et al., 2023). The various forms of data collection through observation processes are vital sources in the said collection; however, since academics are not specialists in the collection technique, there may be some bias that makes the data not so reliable the various forms of data collected by citizen scientists (Depauw et al., 2022).

Citizen science has several advantages for researchers and volunteers, particularly large-scale field investigations. Access to a large pool of enthusiastic volunteers who can collect data at different times across a vast geographic area is one of the benefits for researchers (Kosmala et al., 2016). Citizen science can help initiatives that would otherwise be too ambitious and expensive to run in a climate of limited research funding (Parris et al., 2023); however, these practices can be used unethically, as they in the investigations, said participants could not be considered as part of the investigations through decisions of the principal investigators, since they could be considered part of the learning process.

Mapping the development of citizen science and its literary connotations mention its importance in scientific development with social support, which is why almost all scientific writings published in journals contain citations or bibliographic references that guarantee precedents about what the author intends to offer in his work, in the different areas of knowledge, constituting a data source that allows us to understand what information writers consume (Okoroiwu et al., 2018).



Although bibliometric analysis is subject to numerous controversies and limitations, it is widely accepted as an adequate methodology for the evaluation of extensive scientific production based on the criterion that if a document is mentioned in the documentary corpus of a database, it makes that said selected topic is widely used by researchers interested in said area of knowledge, assuming that there is a relationship between the document that is written and the interest of the reader (Mutz & Daniel, 2018).

According to Meza (2021), bibliometrics uses mathematical and statistical approaches for any written source based on communication aspects. It considers components such as authors, publication title, document type, language, abstract, and keywords, among other metrics of interest that can be analyzed descriptively and analytically.

The first formal definition of bibliometrics (bibliometrics) was achieved around 1969; whose concept proposes that bibliometrics is the application of statistical and mathematical methods to define the processes of written communication, the nature and development of scientific disciplines through counting communication techniques and analysis (Leydesdorff et al., 2016). Therefore, bibliometrics is a methodological tool that arises from the need to quantify certain aspects of science, defined as the calculation of various indicators of scientific publications.

This collaborative approach addresses scientific questions relevant to local communities and promotes the inclusion of diverse perspectives in the research process. The present study explores the benefits and challenges of demoscience and its potential to transform scientific research at a bibliometric level, showing significant trends in the selected theme.

## Methodology

Bibliometrics is a scientific field that quantitatively examines bibliographic data on a given topic (Gorbea, 2016). It focuses on general scientific production, scientific production by nation, language, number of citations, type of scientific technique, author connections, journal impact factor, research disciplines, and keywords, among other things. The results of the bibliometric study can be displayed in a variety of ways, including as maps, tables, charts, figures, graphs, and distribution networks, which can efficiently represent large data sets (Broadus, 1987; Choudhri et al., 2015; Gil et al., 2020).

The bibliometric analysis was the methodology chosen for the present investigation, showing impact metrics regarding the selected topic, and fulfilling the study's objectives: evaluate scientific evolution and determine the productive leadership of which countries have the highest number of correspondence authorships. According to the affiliation of the leading researcher, the type of collaboration of the selected productions, which journals index the documents according to the area of specialization, in addition to visualizing the country, the sources, the author who has presented the most productive development on the subject selected, in addition to the keywords that are being used with citizen science.



This study uses a quantitative analytical approach based on an integrated bibliometric analysis model that, on the one hand, focuses on scientific production where the scientific development of the most significant publication in citizen science or demoscience, extracted from the database is examined of Scopus in the last decade (2013 to 2022). For the selection of documents, those that developed in their titles were chosen: "Citizen Science" OR "community-driven science" OR "community-based research" OR Demoscience\* OR "community science" OR "crowd science" OR "crowd-sourced science" OR "civic science". A first search of documents was made in the titles, abstracts, and keywords, to only opt for the analysis of the titles of the search keywords of the last ten calendar years, obtaining 3,318 documents. However, as it is a relevant subject, the present study tends to consider the open access of information; the documents were downloaded in All Open Access (1,881), as seen in Figure 1, where the diagram illustrating the steps followed in the literature selection process stands out, performing the download on May 6, 2023.



**Fig. 1**-Flowchart of the Literature Selection Process for Analysis

Many writers consider bibliometrics as a statistical technique to evaluate and measure relevant information, such as the number of academic results on a subject or specific variable, as well as to detect the trend that may exist based on the growth of the data (Cisterna and González-Bustamante, 2022; Mao et al., 2018; Soosaraei et al., 2018).

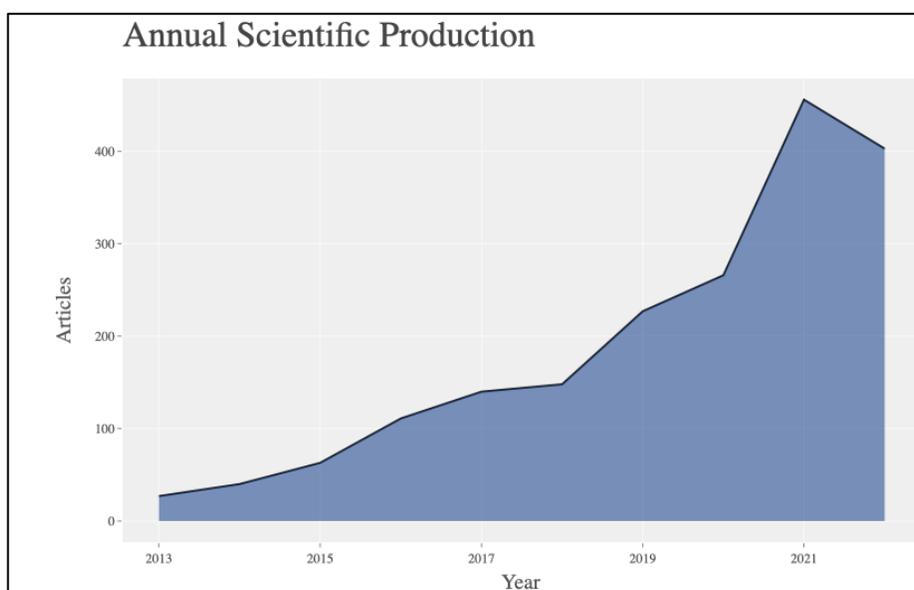
The methodological process was carried out using the Bibliometrix package, which has R Studio programming and the Biblioshiny interface, which allowed us to carry out various analyzes and techniques, as well as using VOSViewer for network maps, as well as Excel to show the primary authors, sources, keywords, among others.



## Results

### *Descriptive analysis*

The descriptive statistics reveal that there has been significant constant growth in the last decade, except for 2022, when a decrease can be seen; however, each database has its editorial processes, which can be updated on different dates that could modify the growth trends in the following years. In the last decade, 1,881 have been made, with the lowest production being in 2013 (n=27) and the highest production in 2021 (n=456), with a standard deviation ( $\sigma$ ) of 148.67, having obtained a weighted growth of 35.03%. Figure 2 shows the growth



**Fig. 2-**Evolution of the scientific production of citizen science in the last decade

### Scientific leadership

It is essential to understand the productive leadership of the documents because, in most cases, the leadership corresponds to the corresponding author, who is affiliated with an institution and a country and is responsible for adhering to the guidelines that each scientific journal requires; however, it is essential to note that most journals only accept one corresponding author. Table 1 shows the top 10 countries that developed the most significant number of documents; in addition, the productive leadership of these countries is displayed.



Table 1-Analysis by leadership productive

Rank	Analysis by leadership productive			
	Country	# of led documents	# of affiliated documents	%
1	USA	318	629	50.56
2	England	187	441	42.40
3	Germany	78	184	42.39
4	Italy	71	145	48.97
5	Spain	62	143	43.36
6	Australia	76	141	53.90
7	Netherlands	50	130	38.46
8	Canada	61	124	49.19
9	Austria	35	88	39.77
10	Francia	35	88	39.77

From the previous table, collaborative production stands out, being divided into single-country production (SCP), which is when a country has made its productions between different institutions or between authors from the same institution; on the other hand, international collaboration is mentioned or multiple country production (MCP) that occurs when more than two authors from different countries have collaborated; however, it is mentioned that a single author has produced 148 documents. Table 2 and Figure 3 show the countries with the most productive leadership according to correspondence authorship, divided into international and national collaboration.



Table 2-Analysis by leadership productive

Rank	Country	Documents	Freq.	SCP	MCP	MCP_Ratio
1	USA	318	0.235556	260	58	0.182
2	United Kingdom	187	0.138519	122	65	0.348
3	Germany	78	0.057778	44	34	0.436
4	Australia	76	0.056296	53	23	0.303
5	Italy	71	0.052593	34	37	0.521
6	Spain	62	0.045926	34	28	0.452
7	Canada	61	0.045185	47	14	0.23
8	Netherlands	50	0.037037	33	17	0.34
9	Austria	35	0.025926	21	14	0.4
10	France	35	0.025926	17	18	0.514

Freq.=Frecuencia del total de documentos; SCP = single country production; MCP = multiple country production

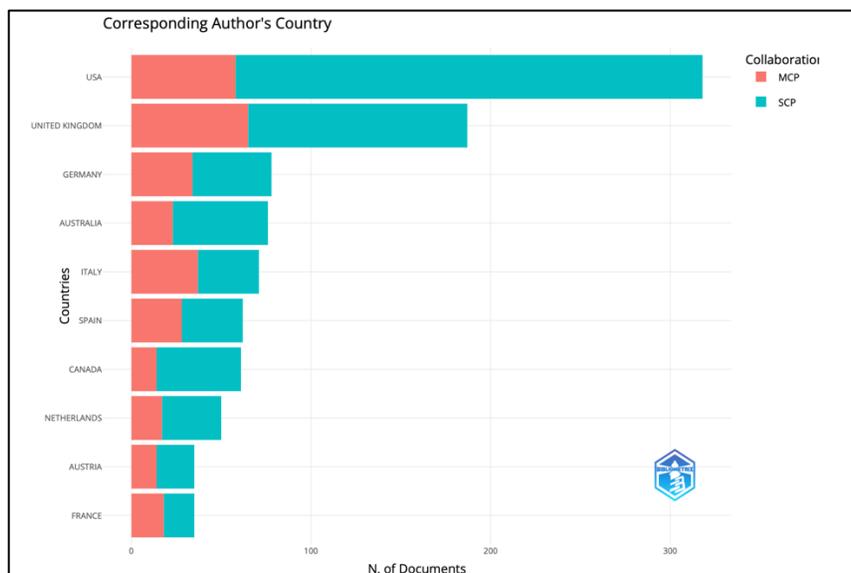
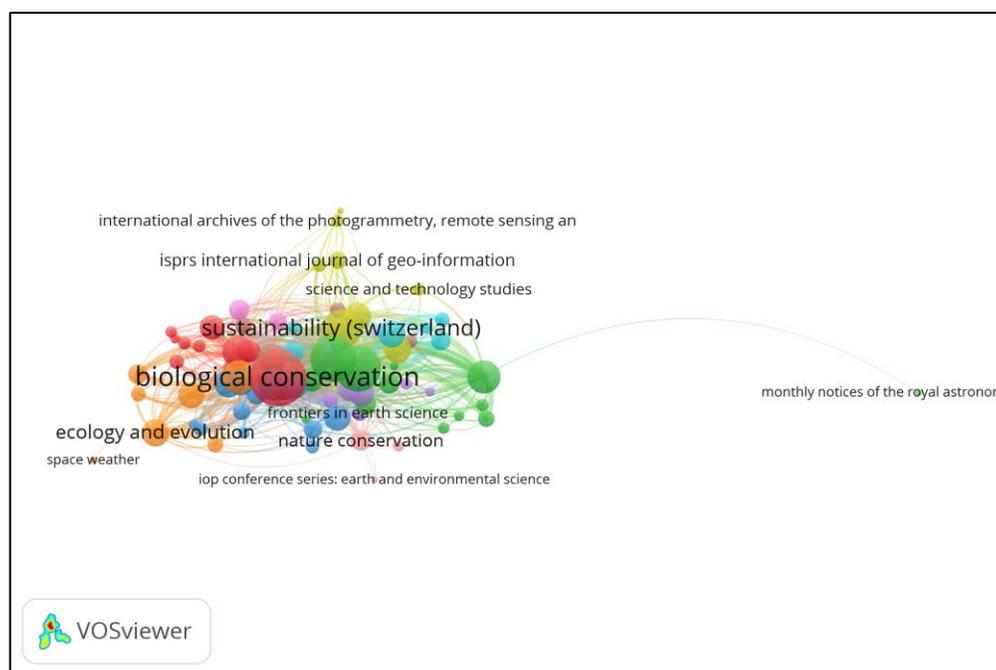


Fig. 3-Distribution of collaborative production leadership by corresponding author's country



## Analysis of scientific sources

Seven hundred twenty-three journals produced the 1,881 documents. The most relevant journals that index documents in the selected area are PLOS One, with 86 journals to its credit, followed by Citizen Science: Theory and Practice (70) and Sustainability (67). However, it can be seen that the journal with the highest number of citations was the Biological Conservation Journal, with 2,781 citations, followed by the PLOS One journal ( $n = 2,510$ ) and the Methods in Ecology and Evolution journal ( $n = 817$ ), with only nine (9) documents. Table 3 shows the top 10 journals and impact factors according to the Scimago Journal and Country Rank (SJR) 2022. Figure 4 shows the network map of the journals by the number of documents and how they are intertwined with other journals depending on the link strength they may be obtaining.



**Fig. 4-**VOSviewer Network map of sources according total link strength

Bradford's law was applied in order to know the specialization of the journals that index documents concerning citizen science; where according to said law, the total number of documents is divided into three groups, where the nucleus (group 1) is the group where a small proportion of journals index a large number of documents, therefore, it is inferred that it is the group where the most significant number of journals specialized in this subject is located, where in the present study it was shown that in the nucleus 24 journals were found that indexed 621 documents, followed by the second one that included 154 journals that indexed 640 documents and finally, the third group of 545 journals that indexed 620 documents. Table 4 and Figure 5 show the journal distribution according to Bradford's law.

Table 3-Top 10 journals with the highest number of indexed documents

Rank	Source	# of documents	# of citation	SJR 2022
1	PLOS One	86	2,510	Q1 0.89
2	Citizen Science: Theory and Practice	70	400	Q1 0.96
3	Sustainability (Switzerland)	67	474	Q1 0.66
4	Journal of Science Communication	48	7745	Q2 0.5
5	Scientific Reports	35	593	Q1 0.97
6	International Journal of Environmental Research and Public Health	29	320	Q2 0.83
7	Biological Conservation	26	2,781	Q1 2.15
8	The Science of Citizen Science	24	403	~
9	Frontiers in Marine Science	23	210	Q1 1.12
10	Bioscience	20	641	Q1 2.42



Table 4-Distribution with Bradford law

Analysis with Bradford's law				
Group	# journals	% journals	# documents	% documents
1 <sup>st</sup> group (core)	24	3.32	621	33.02
2 <sup>nd</sup> group	154	21.30	640	34.02
3 <sup>rd</sup> group	545	75.38	620	32.96
<b>TOTAL</b>	<b>723</b>	<b>100.00</b>	<b>1,881</b>	<b>100.00</b>

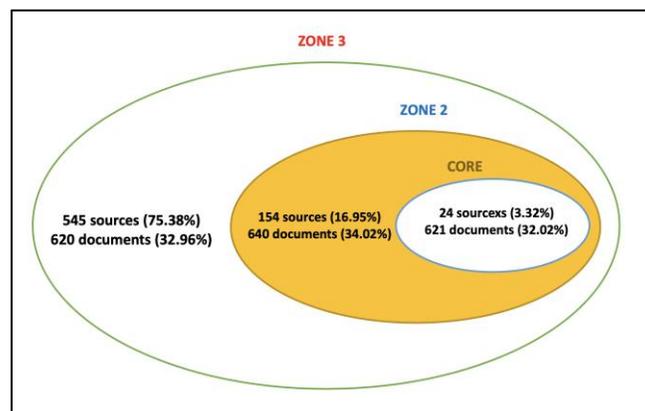


Fig. 5-Visualization of sources and document by groups

From the previous figure, it can be inferred that the nucleus represents the journals with a higher level of specialization in Citizen Science, compared to the second group, which may be a journal with some specialization in the subject, and concerning the third group, the documents do not They were necessarily indexed in journals that explicitly develop on the selected topic, and may be multidisciplinary journals where various research topics are developed.

## Author analysis

Initially, the 1,881 documents were prepared by a total of 8,677 authors; however, some authors demonstrated double registration, having obtained a total of 7,667 authors, with which a ratio of 4.08 authors per document was obtained. The number of scientific productions of the ten best authors registered in Scopus is shown in Table 5.

**Table 5-**Top 10 authors with the most publications about Citizen Science

Rank	Author	Documents	Citations
1	King A. C.	20	353
2	Haklay M.	17	511
3	See L.	15	963
4	Heigl F.	14	389
5	Dörler D.	13	339
6	Roy H.E.	12	583
7	Roy D. B.	12	691
8	Vohland K.	12	403
9	Lintott C.	12	573
10	Hecker S.	11	290



It is worth mentioning that there was an author who produced ten documents (Parrish J.K.) who obtained a total of 1,381 citations, which would indicate that his document is being used as background information for other interested researchers in studying citizen science, as well as its implications.

## Keyword analysis

The analysis of all the keywords (Author keywords and Index keywords) yielded 9,860, grouped into five clusters according to the selected theme and their relationships with other words. With a minimum occurrence of ten keywords, 356 keywords met the threshold, which was determined by calculating the link strength of co-occurrences with other words. These keywords were used primarily by the total number of authors (7,667) who created the 1,881 documents, as shown in Table 6 and Figure 6.

**Table 6-**Keywords with the highest link strength by cluster

<i>Cluster</i>	<i>Color</i>	<i>Keywords</i>
1		animals, physiology, animals, biodiversity, conservation of natural resources, season, aves, monitoring,...
2		citizen science, crowdsourcing, sustainable development, science education, co-creation, innovation,...
3		environmental exposure, air pollution, air quality, pollution monitoring, awareness, costs,...
4		human, female, adult, aged, health promotion, health care policy, Canada, mosquito control, cross-sectional,...
5		genetic, volunteer, genetic, procedures, community participation, research, article,...

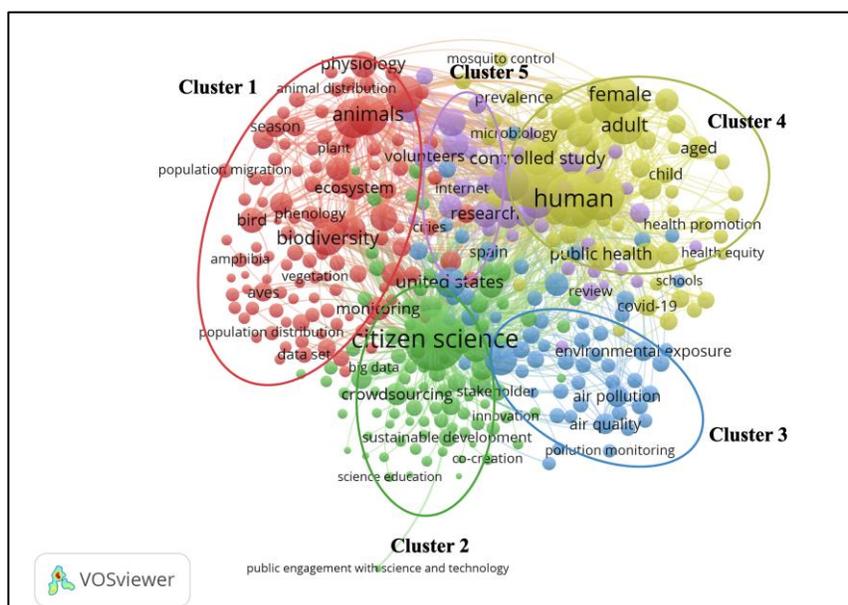


Fig. 6-VOSviewer Network map of co-word analysis for keywords

## Discussion

Citizen science is a research approach in which the public collects data and solves scientific problems. The importance of citizen science to the scientific community is that it allows researchers to access large data sets and conduct research that would otherwise be impossible or extremely expensive.

A viable model for improving citizen science information-seeking skills is to help researchers adapt to the latest research trends for teaching and learning in an environment where they can feel more at ease and learn more effectively. Since reality is in a constant state of flux, it is more important to know what, why, and how; therefore, the process of active participation is shaped and organized through the combined activities of individuals. Therefore, to know is to be interconnected or in constant flux (Ramos-Meza, 2022).

Latin America's contribution to the development of citizen science has shown notable growth and engagement over the past decade. Countries such as Brazil, Mexico, and Argentina have been particularly active in incorporating citizen science into various research initiatives, leveraging the region's unique biodiversity and socio-environmental challenges. Latin American countries have effectively utilized citizen science to address local environmental and public health issues. However, there are concerns regarding the consistency and reliability of data collected by non-professional scientists. Ensuring rigorous training and standardized data collection protocols is essential to mitigate these issues.

Limited funding and resources pose significant challenges. Many Latin American countries need help with financial constraints, which can impact the scale and sustainability of citizen science projects. International collaborations and support from global organizations could help bridge these gaps.

While citizen science has influenced environmental policies and conservation efforts in some Latin American countries, the overall integration into national scientific agendas still needs to be improved. Enhancing the visibility and credibility of citizen science through policy advocacy and government support is crucial. The adoption of technological tools and advanced methodologies has been slower in developing countries than in developed countries. Investing in technology and training can enhance data accuracy and project outcomes.

Citizen science initiatives in Latin America have made strides in including diverse communities and promoting social equity and educational benefits. However, more efforts are needed to ensure the inclusion of marginalized groups and address potential biases in participation and data interpretation. Citizen science is expanding rapidly, with significant contributions from Europe and North America. These regions benefit from robust infrastructure, extensive funding, and strong institutional support. Lessons from their successful models could be adapted to the Latin American context to enhance the effectiveness and impact of citizen science initiatives in the region.

## Conclusions

This study concluded that the number of documents produced on citizen science or demoscience and its conceptual approaches has increased at a weighted annual rate of 35.03% over the last decade. The United States is the country that has participated in the most significant number of scientific productions regarding citizen science, with a total of 629 documents; however, its scientific leadership was 50.56%, followed by England, with a total of 441 documents. In addition, it is essential to mention that 148 documents were only carried out by one author, understanding that citizen science research is usually carried out in groups.

The journal that indexed the most significant number of records was PLOS One (n = 86), having obtained 2,510 citations, followed by the journal Citizen Science: Theory and Practice (n = 70) with 400 citations; however, it could be seen that the journal with the highest number of citations was Biological Conservation (2,781) with only 26 indexed documents. After applying Bradford's law to determine the subject's specialization, it was possible to visualize that 24 journals were found in the core of the journal that indexed 621 documents, understanding that these 24 journals are the most specialized in demoscience research. The 1,881 documents were produced by 7,667 authors, having eliminated double records and having merged them with the VOSViewer thesaurus, showing a productive ratio of 4.08 authors per document, with King A. being the author who produced the most documents (n = 20) with a total of 353 citations, followed by Haklay (n = 17) and See L., (n = 15), with 511 and 963 citations, respectively.



It is essential to mention the importance and relevance of bibliometric studies because they allow identifying trends regarding which topics, authors, journals, and keywords, among other metrics, are considered necessary for the scientific community; this is because we will support their developments by delving into what the academy is investigating and identifying everyday situations that help to understand better the problem being studied. These studies are carried out in all fields and disciplines, including education (Meza, 2021), computer science (Azmeah, 2022), economics and business (Phan Tan, 2022), and various engineering (Bai et al., 2022; Liu et al., 2021), as well as all other fields deemed necessary bibliometric studies, since they are a tool that allows ordering, interpreting and predicting future problems, or how they are being investigated for their investigative relevance.

One of the critical limitations of this study is that only one of the most important databases for researchers was used, such as Scopus; however, it complies with the precepts of the bibliometric study to achieve its goals. Another limitation is having selected only the topics that have appeared in the titles, since when analyzing the titles, abstracts, and keywords, most of the documents mentioned the search keywords; however, research had not necessarily been carried out clearly in citizen science, only having been commented, so the present study was adapted in the best way to download the information in a tangible way to avoid bias in the related search, and complying with the described flowchart.

For future research, it is recommended to use more specific keywords and their synonyms and to be able to search more precisely across fields or academic disciplines. It is also suggested to expand databases such as Web of Science or SciELO to increase the number of documents to be analyzed; however, specific analysis parameters must be specified, and the Scopus database includes the most significant number of scientific history documents globally.

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## Conflicto de interés

Los autores no declaran conflicto de interés

## Declaratoria de autoría

Carlos Samuel Ramos-Meza (autor principal): investigación, análisis formal, procesamiento de datos, redacción (revisión y edición).

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