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Scientometric mapping of gold mining and sustainability:an analysis of scientific production from 2016 to 2020

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Abstract

Contexto: A mineração de ouro é uma prática antiga, na qual consiste na extração e beneficiamento de riquezas minerais presente nos solos. Além disso, em muitas regiões do planeta é considerada a principal atividade de desenvolvimento socioeconômico. Entretanto, a mineração é uma ameaça aos recursos naturais globais e responsável por diversos problemas ambientais em diferentes níveis. Este estudo tem como objetivo compreender tendências, dinâmicas temporais e padrões de publicações relacionadas à temática acerca da mineração de ouro e sustentabilidade. Método: Para isso, foi realizado um levantamento cienciométrico para publicações científicas das bases de dados Scopus da editora Elsevier e Web of Science da editora Clarivate Analytics entre o período de 2016 a 2020. O levantamento identificou 31 artigos que aparecem igualmente nas duas bases de dados, sendo que 7 deles apresentam no mínimo 15 citações. Também foi observado a coocorrência de palavras-chave entre os autores, nesta análise foram encontradas 133 palavras-chaves diferentes, onde 14 tiveram mais de duas ocorrências e foram classificadas em 4 grupos com temáticas distintas. Resultados: O mapeamento cienciométrico demonstrou ser um significativo mecanismo para a pesquisa, apresentando por meio de redes bibliométricas, que os elos entre os autores possuem uma forte interação e preocupação com o tema abordado.

Keywords

gold mining, sustainability, infrastructure, resource extraction, social mobilization, VOSviewer

Introduction

In many regions where economic opportunities are limited, gold mining is an important source of income. Economists believe that the mining industry is a tool to promote economic growth in developing

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countries, as it used to be the main activity of countries that now dominate the world economy (BETANCUR-CORREDOR et al., 2018).

The practice of gold mining begins in specific areas and on a small scale. However, it becomes intense in a short period, as one of the major factors of deforestation and degradation. In addition, when exploration occurs in socially, politically and economically underdeveloped institutions, the wealth generated tends to be poorly invested, the level of social inequality increases and irreversible damage occurs to the environment (BEBBINGTON, A. J. et al., 2018; BETANCUR-CORREDOR et al., 2018).

Scenario changes apply not only to the area where the activity takes place, but also to neighboring places. Where the forests green prevailed, there is room for new infrastructure, an increase in the population attracted by the work opportunities; thus, resulting in an increase in waste deposits, deforestation, capture and discharge of water contaminated by mines. This process significantly damages the quality of water resources and potentially impacts a range of freshwater ecosystem services (MCINTYRE et al., 2016).

Another important aspect is the environmental profile of gold production and its consequences with issues such as energy, through the emission of greenhouse gases, and the contamination of water in solid waste in the extraction stages in different places in the world (NORGATE; HAQUE, 2012). According to Bebbington et al. (2018), this also implies a reformulation in the logistics of obtaining minerals, as the activity affects increasingly aggravating factors in the loss of forests, greenhouse gas emissions and threats to the rights of communities in forested areas in the Amazon, Indonesia and Mesoamerica. Also, investments made in the mining sector are indicative of a future in which forests are immensely threatened, since resource extraction and infrastructure worsen and allow population displacement and expansion further into the forest.

With each new report from the UN intergovernmental panel, concerns about sustainability the extractive sector (as well as other metal production) are growing, consequently increasing pressure to reduce its environmental footprint during the various stages of processing in the supply chain from mining gold ore to refining gold.

To this end, it is necessary to have a set of studies supporting the decision-making process both to broaden the understanding of this concern from a theoretical point of view and of the innovation of new technological production processes. In theory, reducing the environmental footprint should be present in the assessments carried out by researchers dedicated to the subject, both to provide estimates or indicators of the environmental profile of production, as well as in the construction of policies that may align the demands and exercise of sovereignty over these resources within a global scenario in terms of energy, greenhouse gases, water and solid waste, among other problems.

Another important aspect is innovation. For these same researchers to contemplate success in technological development of production processes, it is necessary that the idea circulates and is absorbed, even before being reproduced. For Borchardt and Santos (2014), decision-making tools include the possibility of not only incorporating product/process/technology innovations in innovation processes, but also business models.

The possibility to diagnose it is questioned. One of the options is the use of methods that make it possible to measure the productivity of researchers, groups or research institutions that produce gold. Therefore, it is essential to use specific assessment techniques that may be quantitative or qualitative, or even a combination of both. Among the techniques, we will use scientometrics, which, in turn, proposes to measure the diffusion of scientific knowledge and the flow of information under different

approaches. However, there is the production and innovation of gold production processes aiming to reduce environmental impacts, but we do not know the diffusion centers and their main researchers that have been approaching the subject. In this sense, it is opportune to present its temporal dynamics and understand patterns of related publications, once evaluated, to establish an overview of the subject.

In this sense, this study aims to understand trends, temporal dynamics and understand patterns of publications related to the gold mining and sustainability subjects. For this, an analysis was carried out using scientometric methods for scientific publications of the Scopus (from Elsevier) and Web of Science (from Clarivate Analytics) databases.

Materials and Methods

Bibliographic reviews are basically an analysis of the literature, while, in a complementary way, scientometric analyses quantify scientific production in an attempt to reveal the authors' practices and their socio-organizational structures. Thus, the methodology of this study was structured in the choice of the database, the definition of search descriptors (terms), the metadata collection and the results exploration. The scientific mapping was performed using the VOSviewer software to visualize bibliometric networks and produce the graphics (HOSSEINI et al., 2018).

Data collection

A search was carried out for scientific publications that contained the "gold mining" and "sustainability" terms in the title, abstract or among the keywords from 01/01/2016 to 12/31/2020. The searches were carried out in the Web of Science – Core Collection (Clarivate Analytics) and Scopus (Elsevier) databases. The platforms chosen for gathering information from the study are competing and world-leading multidisciplinary databases. The web-based Web of Science was launched in 1997, while the Scopus database, in 2004 (ZHU; LIU, 2020).

They bring together different categories of journals and different editors, and help to provide global access to much of the scientific literature published internationally. In addition, they are appropriate mechanisms for the construction of bibliographic reviews, as they are comprehensive and provide information on the number of citations per article and other additional information. In such a way, this study assessed the scientific publications in common between the two databases (ZHU; LIU, 2020).

Bibliometric mapping

In the present study, the mapping of science was carried out with the creation of networks through the scientometric analysis of direct citations of journals and documents (articles), authors' citation, co-authorship between authors and countries, and co-occurrence of authors' keywords, looking for patterns, trends, seasonality and outliers.

The bibliometric analysis process was carried out with the help of VOSviewer, a tool capable of loading and exporting information from various sources, allowing the construction and visualization of bibliometric networks (DARKO et al., 2019; MORAL-MUÑOZ et al., 2020).

The graphic mapping of the VOSviewer software presents assessed items (authors, countries, documents and words) in the form of circles. The size of the circle is determined by its weight (relevance calculated by the software), so the larger the item, the more relevant it was. For the analyses, a thesaurus

file was used to converge any variation of keywords, such as abbreviations, plural and synonyms, to a single expression (VAN ECK; WALTMAN, 2021).

Results

Scientific publications

Figure 1 provides information on the number of articles published within the analyzed period, considering the descriptors used in the two researched databases. The year with the highest number of published documents was 2018 with nine articles, followed by 2020, with seven articles.

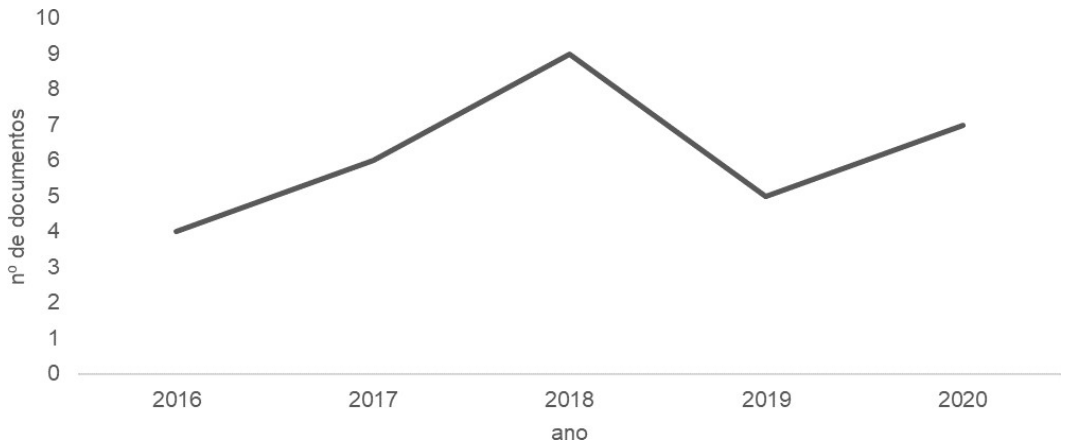

Figure 1. Articles published by year

Journals citation

The journals impact classification was assessed by the Journal Citation Report (JCR) and Scimago Journal Rank (SJR), in which, applying the criterion for journals with a minimum of five citations, among the 31 articles found in the search, the result was a network of 13 journals listed in Table 1.

Articles citation

This scientometric analysis assessed 31 documents that appear equally in the two databases used (Scopus and Web Of Science), with the same descriptors. As a selection criterion, documents with a minimum of 15 citations were filtered to enable the classification of articles (as shown in Table 2), resulting in seven main articles.

Table 1. Journals with a minimum of five citations (ordered by number of citations)

Journal	ISSN	Documents	Citations	*JCR	*SJR
Proceedings of the National Academy of Sciences of the United States of America	0027-8424	1	47	11,205	5,011
Resources Policy	0301-4207	2	34	5,634	1,276
Science of the Total Environment	0048-9697	1	33	7,963	1,795
Extractive Industries and Society	2214-790X	1	29	3,586	0,999
Journal of World Business	1090-9516	1	24	8,513	3,607
Journal of Cleaner Production	0959-6526	1	20	7,246	1,937
Remote Sensing Applications: Society and Environment	2352-9385	1	15	-	0.703
Sustainability (Switzerland)	2071-1050	2	14	3,251	0.612
Revista Facultad de Ingenieria	0120-6230	1	9	-	0.160
International Journal of Life Cycle Assessment	0948-3349	2	8	4,141	1,093
Environmental Monitoring and Assessment	0167-6369	1	5	2,513	0.590
Mineral Processing and Extractive Metallurgy Review	0882-7508	1	5	5,284	0.686
Singapore Journal of Tropical Geography	1467-9493	1	5	1,940	0538

*JCR 2019 *SJR 2020

Authors citation

From the survey carried out, the largest citation network among authors is shown in Figure 2. The larger the “sphere” corresponding to the author, the greater its representation in the citation network is. The color scale indicates the period (year) of publication of the works from this network.

Co-authorship

Figure 3 presents the countries of the authors with the highest number of citations and the published documents.

The largest author collaboration network among countries is represented in Figure 4, obtained after analysis with the help of the VOSviewer software.

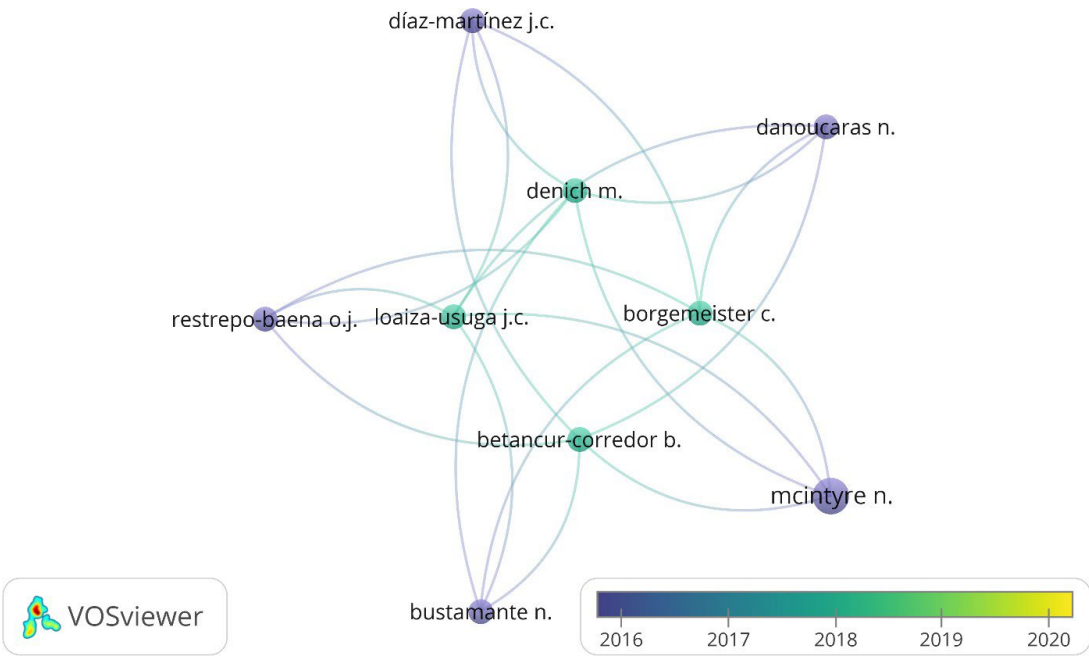

Figure 2. citation network among authors.

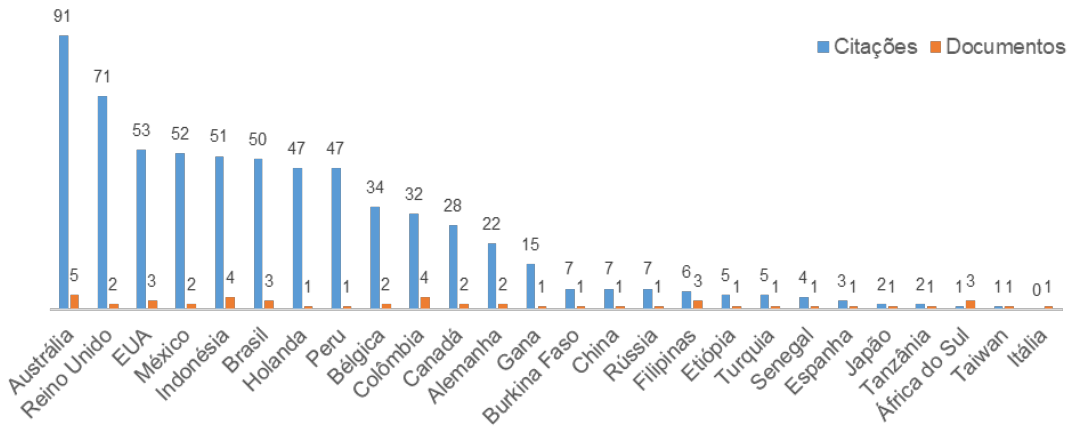

Figure 3. list of citations and documents by country

Table 2. Articles a minimum of 15 citations

Article title	Authors	Citations
Resource extraction and infrastructure threaten forest cover and community rights https://www.pnas.org/content/115/52/13164	Bebbington A. J. et al, 2018	47
A multi-disciplinary approach to understanding the impacts of mines on traditional uses of water in Northern Mongolia https://doi.org/10.1016/j.scitotenv.2016.03.092	Mcintyre N. et al, 2016	33
Explaining fragmented and fluid mobilization in gold mining concessions in eastern Democratic Republic of the Congo, The Extractive Industries and Society https://doi.org/10.1016/j.exis.2017.07.006	Geenen S. et al, 2017	29
Linking or de-linking sustainable mining practices and corporate social responsibility? Insights from Ghana https://doi.org/10.1016/j.resourpol.2016.08.008	Essah M. et al, 2016	27
Multinational mining enterprises and artisanal small-scale miners: From confrontation to cooperation https://doi.org/10.1016/j.jwb.2017.08.004	Yakovleva N. (2018)	24
Gold mining as a potential driver of development in Colombia: Challenges and opportunities https://doi.org/10.1016/j.jclepro.2018.07.142	Betancur-Corredor B. et al, 2018	20
Land use/land cover dynamics using landsat data in a gold mining basin-the Ankobra, Ghana https://doi.org/10.1016/j.rsase.2018.10.007	Obodai J. et al, 2019	15

Co-occurrence of authors' keywords

Co-occurrence of keywords among authors

For the analysis of co-occurrence of the authors' keywords, a thesaurus file was used to converge any variation of keywords, such as abbreviations, plural and synonyms, to just one expression. In this sense, 133 words were found, among which 14 had more than two occurrences and can be observed in the network presented in Figure 5. Also, it was observed that the network of keywords was divided into four groups (Table 3).

Discussion

The choice of the analyzed period was made in an attempt to contextualize the subject in scientific publications with recent approaches, directly reflecting on the perception of the socio-environmental impact of the mining activity in question. The time frame that bibliometric indexes use to evaluate typically ranges from two to ten years. Thus, the five-year time frame was used, the same found in the studies by José et al. (2020). Consequently, an average of six articles published per year was found from 2016 to 2020, so there was no discrepancy regarding the number of publications in each year.

Different databases use different bibliometric methodologies to assess the influence and impact of scientific journals in their respective areas in the scientific community. The Journal Citation Reports (JCR) impact factor is prepared by Clarivate Analytics, as it considers data from articles published by

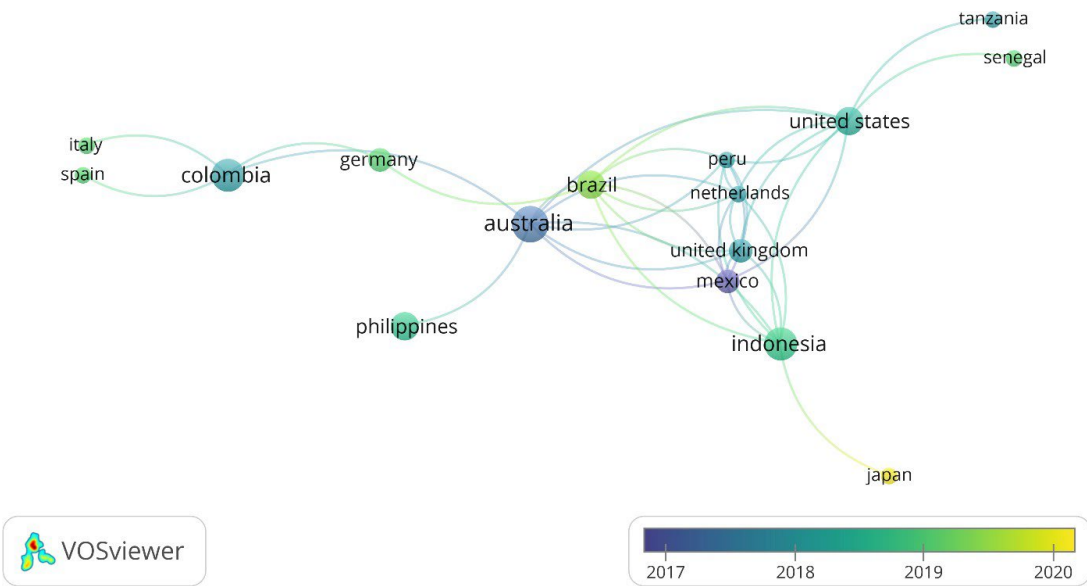

Figure 4. authors' collaboration network among countries

Table 3. Keywords groups

Classification		Number of Occurrences
Red group	corporate social responsibility	3
	environmental conflict	2
	environmental impacts	2
	gold mining	4
	protected areas	2
Green group	environmental sustainability	2
	ghana	3
	livelihoods	2
	mining	4
Blue group	artisanal mining	4
	gold	2
	pollution	2
Yellow group	small scale gold mining	2
	sustainability	5

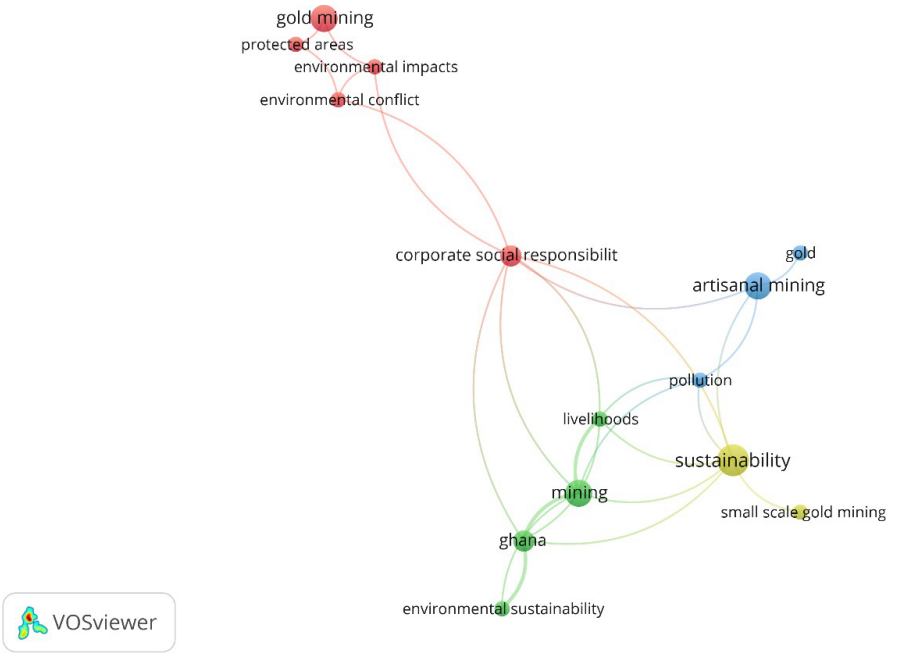

Figure 5. Author keywords network

each indexed journal in the two years prior to the reference year. The SCImago group, which is managed by Elsevier, has the SCImago Journal Rank (SJR) among its indicators (JACSÓ, 2010).

In view of this, it is possible to evaluate the largest network of journals that obtained more than five citations observed in Table 1.

The choice of the SJR indicator, a metric of the Scopus platform, was due to the fact that it is an open access resource that assigns different weight to citations, without the influence of self-citations, and considers the documents of a journal in the denominator of the relevant calculation in its entirety. In addition, the SJR indicator has a larger journal database when compared to Thompson Scientific Journal Citation Reports (JCR) and focuses on the quality of citations a journal receives from others, rather than the absolute number (FALAGAS et al., 2008).

As shown in Table 2, the article with the highest number of citations (47 citations) brings a current approach to the relationship between extraction, infrastructure and forests, combined with a geospatial analysis of forest loss in areas of potential resource extraction, directly reflecting political agreements that bring this extraction as a path to development. Furthermore, it suggests that resource extraction and infrastructure are strengthened, aiding agricultural expansion into forests and allowing population movements, placing forests and rights at risk (BEBBINGTON et al., 2018).

From the point of view of impact and repercussion, the issue of gold extraction has little impact on the literature, especially for those dedicated to the subject.

As it can be seen in the collaboration network of authors among countries, shown in Figure 4, articles published in Australia, United Kingdom, United States and Mexico were more cited by other authors.

The publication of the studies by Bebbington A. J. et al. (2018), despite having the highest number of citations, does not make up the largest citation network among authors. According to Figure 2, the author with the greatest representation in this network is Neil Mcintyre, with the article A multi-disciplinary approach to understanding the impacts of mines on traditional uses of water in Northern Mongolia, which was published in 2016 and describes a case study in Northern Mongolia, a region comprised of a variety of mining styles, from small-scale artisanal mining to a large coal mine, where this activity is carried out in the midst of traditional herding lifestyles. This article notes and causes the impacts on water resources in the area, suggesting that the deterioration of the water resources in the region is mainly due to small-scale gold mining (MCINTYRE et al., 2016).

According to Mcintyre et al. (2016), mining regions radically impact landscapes from the mine design site to the surrounding areas, and may even generate long-term and potentially perpetual impacts on water quality.

Regarding the nationality of the analyzed publications, 26 countries were identified, as shown in Figure 3. In this context, Australia was highlighted, with 91 citations and five published documents. The universities of Queensland and Melbourne were the institutions that published the most, followed by Colombia and Indonesia, both with four published documents.

The analysis of this set of information allowed us to understand trends, temporal dynamics and understand patterns of publications related to gold mining.

It was possible to identify four different groups in view of the co-occurrence of the authors' keywords (red, green, blue and yellow). The red group had the largest number of words referring to the most recent publications in the assessed period, in which the main ideas related to gold mining and the environmental impacts in protected areas and the social responsibilities of mining corporations were presented. The blue group had publications from 2016 to 2018, and studies related to the pollution of artisanal gold mining processes were observed, as well as in the yellow group, which addressed publications from approximately 2018 and on small-scale mining, dealing directly with sustainability. Finally, the green group encompassed publications from the entire assessed period, in the way that, initially, they were related to forest pollution, scientific publications of studies directly to the country of Ghana and recently with an approach to environmental sustainability.

Among the seven articles with more than 15 citations listed in Table 2, it was possible to observe a relationship between the most cited words within each document, divided into three main networks. The first network highlights words such as "water", "basin", "study", "social mobilization" and "sustainability", while the second network highlights "challenge", "country", "Colombia", "mining" and "gold mining". The third core network emphasizes the words "forest loss", "infrastructure", "resource extraction", "threats" and "small-scale mining".

As expected, a strong link between the words "gold mining" and "sustainability" was identified, considering the search criteria of this mapping.

Conclusion

Scientific mapping using the VOSviewer software proves to be an important tool for this type of research, enabling the construction and visualization of bibliometric networks.

The time frame analyzed highlights that gold mining and sustainability are subjects addressed simultaneously in scientific works from several countries on different continents. However, it shows us that the amount of works published in the analyzed period refers to a low scientific interest in approaching this subject, which is of great environmental importance.

It was identified that the different study groups have similar patterns in their approaches to the subject. Keywords such as “infrastructure”, “threat”, “challenge”, “sustainability”, “gold mining”, “water” and “social mobilization” make up the main network of studies, showing a strong correlation and concern with the proposed subject.

Credits:

Amanda Schramm: Conceptualization, writing original draft, **João Henrique Rodrigues:** Writing original draft, **Luiz Vitor da Silva**: Data curation, editing and **Natalia Cristina Costa**: Final review

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References

Amos, D., Albert, C., Xiaosen, P. C. H. (2019). A scientometric analysis and visualization of global green building research. *Building and Environment*, *149*, 501–511.

Bebbington, A. J., Bebbington, D., Humphreys, Sauls, L. A., Rogan, J., Agrawal, Sumali, Gamboa, C., Imhof, A., Johnson, K., Rosa, H., Royo, A., Toumbourou, T., Verdum, R. (2018). Resource extraction and infrastructure threaten forest cover and community rights. Proceedings of the National Academy of Sciences (v. 115), pp. 13164–13173.

Betancur-Corredor, B., Loaiza-Usuga, J. C., Denich, M., Borgemeister, C. (2018). Gold mining as a potential driver of development in Colombia: challenges and opportunities. *Journal Of Cleaner Production*, pp. 538–553.

Borchardt, P., Santos, G. V. D. (2014). https://www.redalyc.org/articulo.oa?id=97330611011

Falagas, M. E., Kouranos, V. D., Jorge, R., Arencibia (2008). Karageorgopoulos, Drosos E. Comparison of SCImago journal rank indicator with journal impact factor. *The FASEB Journal*, (8), 2623–2628.

Hosseini, M., Reza, Martek, Igor, Z. E., Kazimieras, A., Ajibade, A., Mehrdad, A., Nicholas, C. (2018). https: //doi.org/10.1016/j.autcon.2017.12.002

Jacsó, P. (2010). Comparison of journal impact rankings in the SCImago Journal & Country Rank and the Journal Citation Reports databases. *Online Information Review*, *34*, 642–657.

Jan, W. V. E. N., Ludo (n.d.). Manual for vosviewer version 1 .6.17. (pp. 53–53). Netherlands: .

José, S. A., Pereira, Carmo, S. A., Vieira, L., Cardoso, L. R., Portela, C., Ferrari, S. R., Pinto (n.d.). Anna Carolina Rodrigues. Farias, Paulo Vitor Alves. 2020. The communication of difficult news about the approach applied to oncology: a bibliometric review. *Research, Society and Development*, (9).

Mcintyre, N., Bulovic, Nevenla, Cane, Mckenna, P. (2016a). https://doi.org/10.1016/j.scitotenv.2016.03.092

Moral-Muñoz, J. A., Herrera-Viedma, E., Santisteban-Espejo, A., Cobo, M. J. (2020). Software tools for conducting bibliometric analysis in science: An up-to-date review. *Profesional De La Informacion*, *29*.

Norgate, T., Nawshad, Haque (2012). Using life cycle assessment to evaluate some environmental impacts of gold production. *Journal of Cleaner Production*, pp. 53–63.

Zhu, J., Liu, W. (2020). A tale of two databases: the use of Web of Science and Scopus in academic papers. *Scientometrics*, *123*, 321–335.