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Artificial Intelligence and Machine Learning in Governmental Artisanal Mining: Current Status, Development, and Future Directions

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Abstract: The COVID-19 pandemic is not an obstacle research and development implementation, one of which uses secondary data and bibliometric methods. Studies on mining regulation are generally about formal mining in the form of corporations, while artisanal mining is considered illegal, criminal, and its operation is prohibited because it inhibits the growth rate of a country's socio-economic development. This study aims to analyse previous studies on governmental artisanal mining published in the Scopus database and data processing using VOSviewer software. The findings show that there are 287 documents on governmental artisanal mining published from 1987 to 2023. United Kingdom, Canada, and United States occupy most countries of publication as the place of author affiliation. Meanwhile, the author who produced the largest number of publications and is cited mostly was Galvin Hilson. The top ten publications based on the number of citations were obtained by the majority of journals ranked in Quartile 1 with the top rankings being Resource Policy Journal, Journal Cleaner Production, and Science of the Total Environment Journal. The dominant keywords used by authors were "artisanal and small-scale mining", "formalization", "illegal mining", "Ghana", and "gold". The data revealed that there are still limited studies discussing the link between the governmentality of artisanal mining and local politics, other mining, and identity, as well as its relationship with the COVID-19 pandemic. Future studies can further develop the case of governmental artisanal mining from a social critical perspective and in comparison with other types of mining across countries.

Keywords: Bibliometrics, Knowledge mapping, Text mining, VOSviewer

Introduction

Artisanal or illegal mining tends to be one of the focuses of rural community livelihoods. Even though it is prohibited by the government because its activities are without permits and are not standardized, subsistence living conditions and inability of supporting their households due to poverty conditions require them to diversify their income and to switch to non-agricultural economy, especially artisanal mining (Eng, 2014; Hilson, 2012; Hilson, 2009, 2016; Manolache & Viorica Bedrule-Grigoruģă, 2014), in Africa, India and Indonesia.

Community mining is small-scale mining managed by local communities without permits using simple technology (Hilson & Mcquilken, 2014). This was viewed negatively by the general public, triggering criticism against these activities (Hilson, 2016). For example, mining is closely related to poverty, has negative impacts on environment and health, causes social conflict, and does not support development programs. However, this sector absorbs a lot of labour, generates large incomes for the poor, and is linked to subsistence agriculture in rural areas (Buxton, 2013; Maconachie & Hilson, 2016).

Governmental and artisanal mining have an important relationship. How have previous studies reviewed it? This bibliometric study is useful in bridging and displaying links with previous studies on a macro level. Bibliometrics studies on this issue are limited. Morante-Carballo et al. (2022) conducted a bibliometric analysis

of artisanal and small-scale mining but did not consider their relevance to these mining settings. Although there have been bibliometric studies using VOSviewer (Cancino et al., 2017; Chandra et al., 2016; Sun & Yuan, 2020), these studies do not cover this topic and most of the sources come from the Web of Science (Aleixandre-Tudó et al., 2018; Cancino et al., 2017; Popova et al., 2013; Sun & Yuan, 2020). This is perhaps the first study to use bibliometric methodology and VOSviewer to examine governmentality and artisanal mining. This article can be a reference for researchers, policymakers, or science practitioners in making decisions and planning future research or establishing networking with related authors. This paper highlights the novelty of recent developments in the field of governmentality and artisanal mining as well as opportunities for further research, as well as a bibliometric analysis of Scopus-indexed articles by integrating visualization analysis from VOSviewer software.

Conducting field studies on artisanal mining, though, has its own challenges. For example, the COVID-19 pandemic having hit almost all parts of the world has made difficult the implmentation of research activities as well as mining activities themselves. However, through the development of technology, we are now able to obtain data as well as process it in a short time with accurate results. Artificial intelligence (AI) has now become a necessity, even part of the daily routine penetrating every aspect of life. AI has an ability of automizing the repetition of tasks and predicting the results. This certainly improves the humans' ability of making decisions.

AI is a broad term to describe computer intelligence with the ability of performing tasks in a human-like manner, including the process of reasoning, meaning, generalization, as well as learning from experience. On the other hand, Machine Learning (ML) is a further development, an aspect, or a branch of AI. If AI is a concept showing a direction to go, ML is an effort to define it more specifically. Through ML, data can be easily identified and if is trained correctly, it will be possible to make predictions in the future because its algorithmic capabilities allow it to produce more accurate information, (Goksel & Bozkurt, 2019).

Artificial intelligence and machine learning help manage, process, and evolve data. For this reason, these mechanisms are important in supporting the alignment of knowledge needs and development, especially improving skills learning and collaborative learning in higher education institutions (Kuleto et al., 2021). In this governmental artisanal mining study, AI & ML is important in reviewing documents more effectively and efficiently, thus supporting the achievement of better quality in literature mapping and subsequent predictions on this issue. Through this system, it is possible for researchers and academics to calibrate knowledge development in improving the overall experience and quality of their studies, both in individual and institutional contexts (Chen et al., 2020).

This research aims to analyse general trends in governmentality artisanal mining in the Scopus database. The Scopus database still tends to be a dominant and trusted reference because it has a high impact factor. A scientific journal has a performance metric or indexing in identifying the number of citations as an indicator of the quality of a paper. So, the questions to be answered are:

1. How do the governmental artisanal mining publications develop across the Scopus database?
2. Who are the influential authors and in what countries are these publications?
3. What are the main reference documents?
4. What are the dominant topics reviewed by the authors?
5. What are the topic gaps or opportunities for further study?

Method

This research uses a bibliometric approach as part of the quantitative research method (van Eck & Waltman, 2014; Waltman & Noyons, 2018). This study is useful as an evaluation research in describing the quality of publications through statistical indicators of citations (Onsunkentan, 2021; Padrós-Cuxart et al., 2016). This type of research is very useful for research and development in finding research gaps, as well as decision and policy making (Nandiyanto et al., 2020).

At this stage, the research team searched for some documents on February 2, 2023, throughout the Scopus database. Researchers searched for the title, abstract, and keywords with the keywords "government" or "governmentality" and "artisanal mining" or "small mining" or "illegal mining". We limited the search to English-only publications. This resulted in 287 documents for further analysis in this study.

Once the data was obtained, the next process was to analyse the literature using VOSviewer 1.6.16 software. The large amount of data allowing for the presentation with an attractive display through visualization of bibliometric network analysis, such as the "Visualization of Similarity" (VOS) technique (van Eck & Waltman, 2014). An attractive display makes the correlation visible and the message conveyed, thus understandable and memorable to the readers (Ranjbar-Sahraei & Negenborn, 2017).

Result and Discussion

Publication Trends

The results of the literature search in the Scopus database with the theme "Government Artisanal Mining" have received enough attention since 1987 until now. Based on primary data, a total of 287 documents on Government Artisanal Mining were found. The first document is a scientific article published in 1987 entitled "Empresa Nacıonal De Mınerıa – Chıle" by Crozier (1987) published by "Mining Magazine" Volume 157, Issue 4, October 1987. Meanwhile, a significant increase in publications was found in 2008 with 34 documents, then increased to 38 documents (2019), and 40 documents (2022) (See **Figure 1.**). This provides a greater opportunity for the discourse on Governmental Artisanal Mining to remain to be a trend in the future.

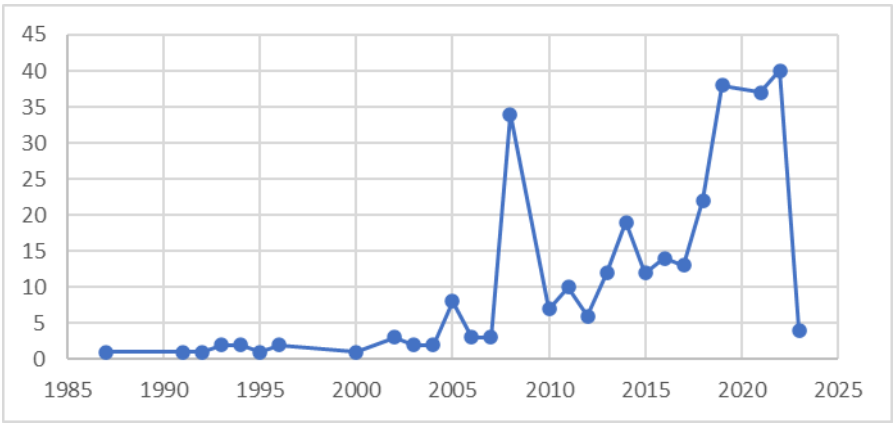


Figure 1. Trend publication

Most of 228 (80%) Governmental Artisanal Mining publications are made article format , 17 (5.96%) in book chapter, 16 (5.61%) in review, 15 (5.26%) in conference paper, 6 (2.10%) in note, 2 (0.70%) in letter and 1 (0.35%) in book format.

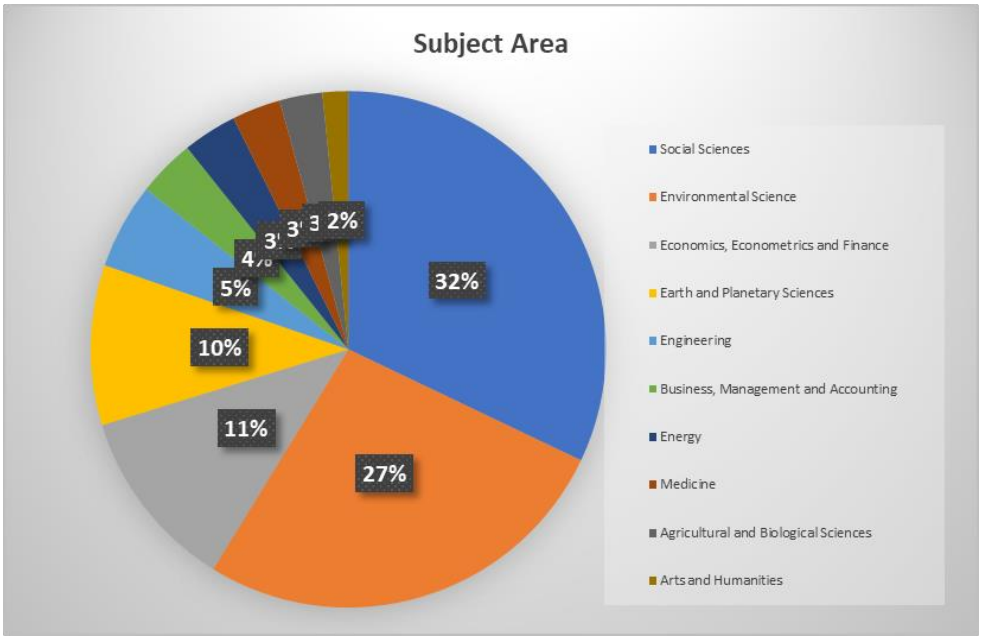
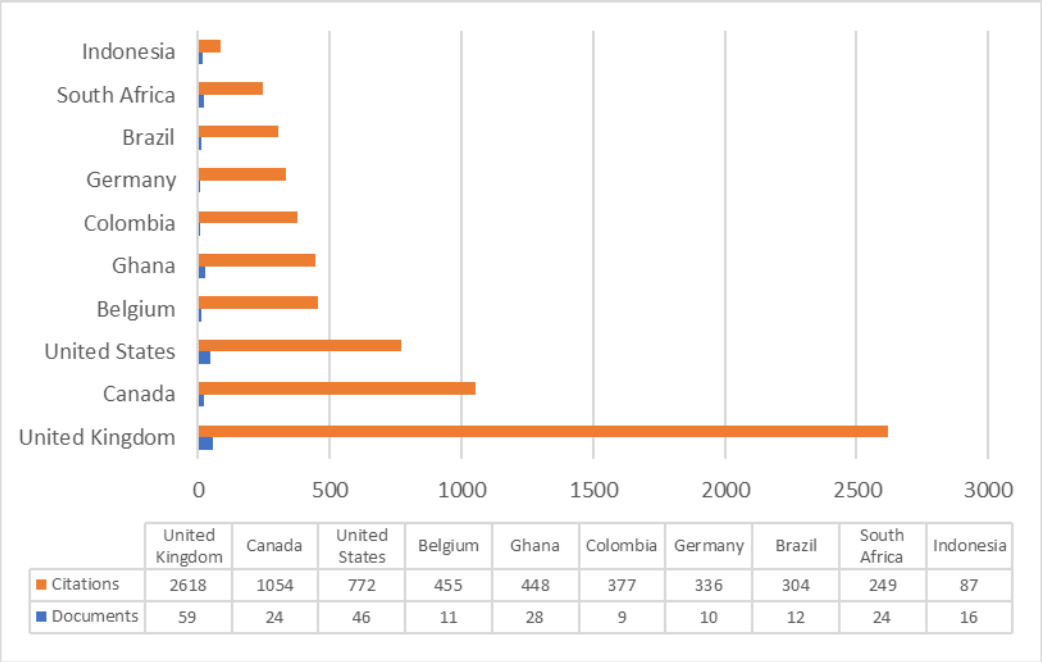


Figure 2. Subject area

There are 21 research subject areas of Governmental Artisanal Mining. Ten (10) subject areas dominate the writing: (1) Social Sciences 179 (32%), (2) Environmental Science 149 (27%), (3) Economics, Econometrics and Finance 64 (11%), (4) Earth and Planetary Sciences 56 (10%), (5) Engineering 30 (5%), (6) Business, Management and Accounting 20 (4%), (7) Energy 19 (3%), (8) Medicine 17 (3%), (9) Agricultural and Biological Sciences 15 (3%), and (10) Arts and Humanities 9 (2%) (see Figure 2.).

Country

An analysis was also conducted based on the author's country of origin. It is known that there are 64 countries of origin of authors with this theme. The data presented in Figure 3 are the top 10 (ten) countries with the highest number of documents and citations. In terms of the author's country of origin (1) the United Kingdom is the country with the highest number of articles and citations resulting in 59 documents and 2,618 citations, followed by (2) Canada with 24 documents and 1,054 citations, followed by (3) United States with 46 documents and 772 citations, (4) Belgium with 11 documents and 455 citations, and (5) Ghana with 28 documents and 448 citations. Germany ranked 7th with 10 documents and 336 citations, and Indonesia ranked 10th with 16 documents and 87 citations.



	United Kingdom	Canada	United States	Belgium	Ghana	Colombia	Germany	Brazil	South Africa	Indonesia
Citations	2618	1054	772	455	448	377	336	304	249	87
Documents	59	24	46	11	28	9	10	12	24	16

Figure 3. Author's contributions based on countries

The results of bibliometric analysis based on network visualization in Figure 4 show that there are 7 clusters and 32 countries of the Governmental Artisanal Mining constituent network with at least 1 document and 15 citations for a country. Cluster 1 (red) shows a network of authors from 6 countries: Australia, Canada, Colombia, Ecuador, Mexico, and the United States. Cluster 2 (green) shows the network of authors from 6 countries: Austria, Denmark, Germany, Netherlands, Sweden, and Tanzania. Cluster 3 (blue) shows the network of authors from 5 countries: Malaysia, Nigeria, Pakistan, South Africa, and Zimbabwe. Cluster 4 (yellow) shows the network of authors from 5 countries: Belgium, Brazil, Indonesia, Japan, and Mozambique. Cluster 5 (purple) shows the network of authors from 4 countries: France, Kenya, Portugal, and Switzerland. Cluster 6 (light blue) shows the network of authors from 2 countries: Egypt and Ghana and finally Cluster 7 (Orange) shows the network of authors from 2 countries: Sierra Leone, and the United Kingdom. Based on Fıgure 4 It can be seen that the United Kingdom, the United States, and Canada are the countries with the most publication contributions as seen from the largest nodes. These three countries are also connected to many authors from the network across all clusters.

Out of 547 institutions from which the authors come in the theme of Governmental Artisanal Mining, the 10 (ten) institutions receiving the most citations from published documents are presented in Table 1. We limit the data processing to the least number of documents an organization has (2) and the least number of citations an organization has (25). The findings show that the University of British Columbia is the institution publishing the most (5) documents (TP), while the institutions getting the most citations for published articles are UCSIR-

National Metallurgical and Korea Institute of Geoscience and Mineral Resources with 396 citations each. Of the 10 (ten) institutions publishing the most publications, UCSIR-National Metallurgical and Korea Institute of Geoscience and Mineral Resources are institutions publishing publications with the highest quality documents of 198 (TC/TP). This means that every 1 document is cited 198 times.

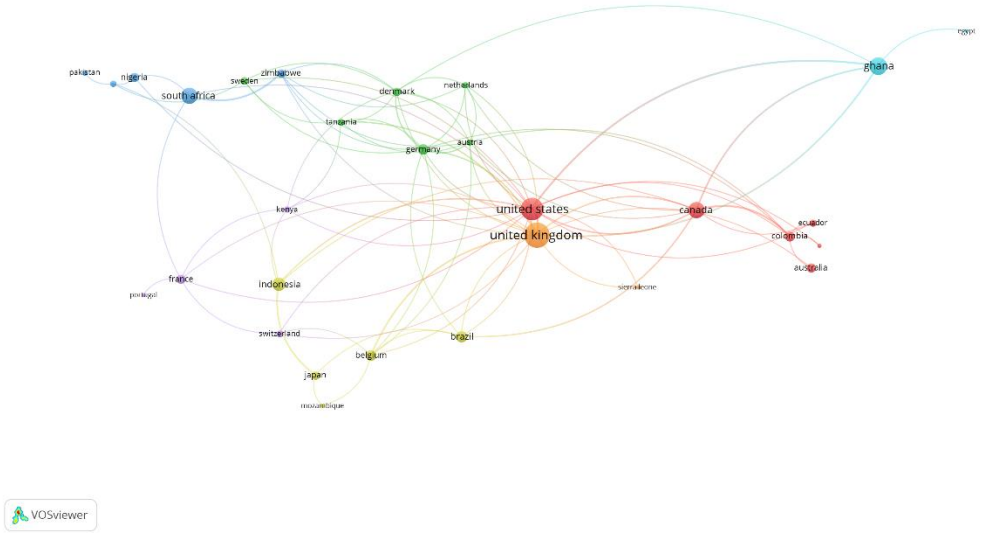


Figure 4. Author network based on state affiliation

Table 1. Top 10 author affiliation institutions

Rank	Institution	TC	TP	TC/TP
1st	UCSIR – National Metallurgical Laboratory	396	2	198
2nd	Korea Institute of Geoscience and Mineral Resources	396	2	198
3rd	University of London	249	2	124.5
4th	University of Surrey	237	4	59.25
5th	University of British Columbia	204	2	102
6th	University of British Columbia	201	5	40.2
7th	University of Surrey	142	2	71
8th	University of Bath	58	2	29
9th	University of the Witwatersrand	55	2	27.5
10th	University of Surrey	36	2	18

TC: Total Citation
TP: Total publication

Prolific Author

The findings show that 656 authors collaborated to write on the theme of Governmental Artisanal Mining from 1987 to 2023. From Table 2**,** we can see the top 10 (ten) dominant authors by the number of citations.

Table 2. Top 10 authors researching "Governmental Artisanal Mining"

Rank	Author Name	Institutions	Number of Paper	Number of Citations	Quality of Paper
1st	Gavin Hilson	University of Surrey, UK	25	1632	65.28
2nd	Abby Hilson	Royal Holloway University, UK	4	316	79
3rd	James Mcquilken	University of Surrey, UK	4	218	54.5
4th	Roy Maconachie	University of Bath, UK	7	330	47.17
5th	Steven Van Bockstael	University of Ghent, Belgium	4	166	41.5
6th	Sadia Mohammed Banchirigah	University of Manchester, UK	3	418	139.3
7th	Peter Cordy	Yale University	3	267	89
8th	Marcello M. Veiga	University of British Columbia, Canada	11	820	74.54
9th	Sara Geenen	University of Antwerp, Belgium	4	235	58.75
10th	Samuel J. Spiegel	University of Edinburgh, UK	6	163	27.16

The author who published the most documents (Number of Papers) and received the most citations (Number of Citations) was Gavin Hilson (University of Surrey Business School) with 25 documents and 1,632 citations. The author with the best paper quality (Quality of Paper) is Sadia Mohammed Banchirigah (University of Manchester, Manchester, UK). For more details on the number of publications, the number of citations, and the quality of publications each author has can be seen in Table 2 below.

Source of Publications

From 1987 to 2022, 152 publication sources published publications related to this theme. Of the 152 publication sources, 10 publication sources publish the most documents related to the theme of Governmental Artisanal Mining (see Table 3.). The ten publication sources are on average still indexed by Scopus in 2021 so that CiteScore, SNIP, and SJR can still be accessed in each publication source.

The Resources Policy journal is the publication source contributing mostly to publishing Governmental Artisanal Mining writings as well as getting most citations from the published documents, 39 papers and 1,027 citations. For more details, the Top 10 publication sources can be seen in Table 3 below.

Table 3. Top 10 sources of publication

Rank	Source Title	Q		Cite Score (2021)	SNIP (2021)	SJR (2021)	Number of Papers	Number of Citations
1st	Resources Policy	Q1	United Kingdom	7.6	1.996	1.461	39	1027
2nd	Journal of Cleaner Production	Q1	United Kingdom	15.8	2.444	1.921	5	545
3rd	Science of the Total Environment	Q1	Netherlands	14.1	2.175	1.806	4	425
4th	Natural Resources Forum	Q2	United Kingdom	3.8	1.009	0.686	10	407
5th	Hydrometallurgy	Q1	Netherlands	7.3	1.363	0.799	2	396
6th	Geoforum	Q1	United Kingdom	5.9	1.737	1.424	8	376
7th	Extractive Industries an Society	Q1	Netherlands	5.2	1.463	0.971	18	350
8th	Development and Change	Q1	United Kingdom	5.4	2.362	1.607	3	334
9th	Resources	Q2	Switzerland	6.4	1.429	0.742	1	312
10th	Political Geography	Q1	United Kingdom	4.9	2.092	1.369	1	193

Citation

Also, the results of data processing can show bibliographic coupling in this Governmental Artisanal Mining publication based on the document. Bibliographic coupling is useful in seeing the relationship between the documents. The results from the following 12 clusters are presented in Figure 4.

Cluster 1 (red) consists of:

1. Clean artisanal gold mining: a utopian approach? (Hinton et al., 2003)
2. Mercury contamination from artisanal gold mining in Antioquia, Colombia: The world's highest per capita mercury pollution (Cordy et al., 2011)
3. Abandoned artisanal gold mines in the Brazilian Amazon: A legacy of mercury pollution (Veiga & Hinton, 2002)
4. Review of barriers to reduce mercury use in artisanal gold mining (Veiga et al., 2014)

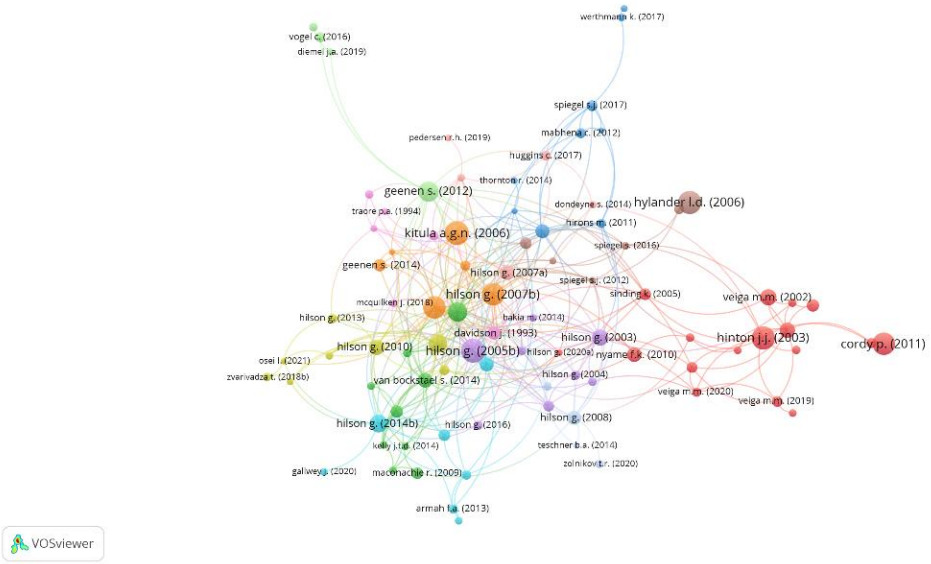


Figure 5. Document by citation

Cluster 2 (green) consists of:

1. Deagrarianization, reagrarianization and local economic development: Reorientating livelihoods in African artisanal mining communities (Banchirigah & Hilson, 2010)
2. The persistence of informality: Perspectives on the future of artisanal mining in Liberia (Bockstael, 2014)
3. Artisanal and small-scale mining and the Sustainable Development Goals: Opportunities and new directions for sub-Saharan Africa (Gavin Hilson & Maconachie, 2020)

Cluster 3 (blue) consists of:

1. Shifting Formalization Policies and Recentralizing Power: The Case of Zimbabwe's Artisanal Gold Mining Sector (S. J. Spiegel, 2015b)
2. EIAs, power and political ecology: Situating resource struggles and the techno-politics of small-scale mining (S. J. Spiegel, 2017)
3. Mining with a 'Vuvuzela': reconfiguring artisanal mining in Southern Zimbabwe and its implications to rural livelihoods (Mabhena, 2012).

Cluster 4 (yellow) consists of:

1. Artisanal and small-scale mining (ASM) in sub-Saharan Africa: Re-conceptualizing formalization and 'illegal' activity (Gavin Hilson et al., 2017)
2. Child Labour in African Artisanal Mining Communities: Experiences from Northern Ghana (Gavin Hilson, 2010)
3. Digging for Survival and/or Justice? The Drivers of Illegal Mining Activities in Western Ghana (Andrews, 2015)

Cluster 5 (purple) consists of:

1. Structural Adjustment and Subsistence Industry: Artisanal Gold Mining in Ghana (Gavin Hilson & Potter, 2005)
2. Why Is Illegal Gold Mining Activity so Ubiquitous in Rural Ghana? (Gavin Hilson & Potter, 2003)
3. Small–scale mining in South Africa: Past, present and future (Mutemeri & Petersen, 2002)

Cluster 6 (light blue) consists of:

1. Chinese participation in Ghana's informal gold mining economy: Drivers, implications and clarifications (Gavin Hilson et al., 2014)

2. Soon there will be no one left to take the corpses to the morgue: Accumulation and abjection in Ghana's mining communities (Bush, 2009)
3. Conflict, collusion and corruption in small-scale gold mining: Chinese miners and the state in Ghana (Crawford & Botchwey, 2017)

Cluster 7 (orange) consists of:

1. The environmental and socio-economic impacts of mining on local livelihoods in Tanzania: A case study of Geita District (Kitula, 2006)
2. Strained relations: A critical analysis of the mining conflict in Prestea, Ghana (Gavin Hilson & Yakovleva, 2007)
3. Challenges with eradicating illegal mining in Ghana: A perspective from the grassroots (Banchirigah, 2008)
4. Dispossession, displacement and resistance: Artisanal miners in a gold concession in South-Kivu, Democratic Republic of Congo (Geenen, 2014)

Cluster 8 (brown) consists of:

1. Environmental costs of mercury pollution (Hylander & Goodsite, 2006)
2. Large and artisanal scale mine development: The case for autonomous co-existence (Gavin Hilson et al., 2020)
3. Implications of the Minamata Convention on Mercury to informal gold mining in Sub-Saharan Africa: from global policy debates to grassroots implementation? (S. Spiegel et al., 2015)

Cluster 9 (pink) consists of:

1. The transformation and successful development of small-scale mining enterprises in developing countries (Davidson, 1993)
2. Formalizing artisanal mining 'spaces' in rural sub-Saharan Africa: The case of Niger (Gavin Hilson et al., 2019)

Cluster 10 (dark orange) consists of:

1. To move or not to move: Reflections on the resettlement of artisanal miners in the Western Region of Ghana (Gavin Hilson et al., 2007)
2. A 'cartography of concern': Place-making practices and gender in the artisanal mining sector in Africa (Huggins et al., 2017)

Cluster 11 (light green) consists of:

1. A dangerous bet: The challenges of formalizing artisanal mining in the Democratic Republic of Congo (Geenen, 2012)
2. Terr(it)or(ies) of Peace? The Congolese Mining Frontier and the Fight Against "Conflict Minerals" (Vogel & Raeymaekers, 2016)

Cluster 12 (sky blue) consists of:

1. Fair trade gold: Antecedents, prospects and challenges (Gavin Hilson, 2008)
2. Effects of the government's ban in Ghana on women in artisanal and small-scale gold mining (Zolnikov, 2020)

The 285 Governmental Artisanal Mining documents were found to contribute to 6,752 citations. This finding shows that on average, one document contributes to 23.69 citations (equivalent to 24 citations). The publications receiving the most citations were in Article and Review formats (see Table 4**.**).

First, publications mostly cited in article format consisted of three articles: (1) "The environmental and socio-economic impacts of mining on local livelihoods in Tanzania: A case study of Geita District" by Kitula in 2006 (Kitula, 2006), published in the Journal of Cleaner Production with 223 citations and an annual average citation of 13.11; (2) "Structural Adjustment and Subsistence Industry: Artisanal Gold Mining in Ghana" by Hilson & Potter in 2005 (Gavin Hilson & Potter, 2005), published by Development and Change, with 217 citations and an

average annual citation of 12.05; (3) "Clean artisanal gold mining: a utopian approach?" by Hinton et al 2003 (Hinton et al., 2003), published by the Journal of Cleaner Production, with 207 citations and an average annual citation of 10.35.

Table 4. Top 10 publications

Rank	Title	Year	Source Title	Document Type	Total Citations	TC/Y
1st	Review on hydrometallurgical recovery of rare earth metals (Jha et al., 2016)	2016	Hydrometallurgy	Review	344	49,14
2nd	Rare earth elements: Overview of mining, mineralogy, uses, sustainability and environmental impact (Haque et al., 2014)	2014	Resources	Review	312	34,66
3rd	The environmental and socio-economic impacts of mining on local livelihoods in Tanzania: A case study of Geita District (Kitula, 2006)	2006	Journal of Cleaner Production	Article	223	13,11
4th	Structural Adjustment and Subsistence Industry: Artisanal Gold Mining in Ghana (Gavin Hilson & Potter, 2005)	2005	Development and Change	Article	217	12,05
5th	Clean artisanal gold mining: a utopian approach? (Hinton et al., 2003)	2003	Journal of Cleaner Production	Review	207	10,35
6th	Environmental costs of mercury pollution (Hylander & Goodsite, 2006)	2006	Science of The Total Environment	Article	201	11,82
7th	Strained relations: A critical analysis of the mining conflict in Prestea, Ghana (Gavin Hilson & Yakovleva, 2007)	2007	Political Geography	Article	193	12,06
8th	Mercury contamination from artisanal gold mining in Antioquia, Colombia: The world's highest per capita mercury pollution (Cordy et al., 2011)	2011	Science of The Total Environment	Article	190	15,83
9th	Challenges with eradicating illegal mining in Ghana: A perspective from the grassroots (Banchirigah, 2008)	2008	Resources Policy	Article	186	12,4
10th	A dangerous bet: The challenges of formalizing artisanal mining in the Democratic Republic of Congo (Geenen, 2012)	2012	Resources Policy	Article	153	13,90

Second, publications mostly cited in Review format are (1) "Review on hydrometallurgical recovery of rare earth metals" by Jha et al in 2016 (Jha et al., 2016), published by Hydrometallurgy with 344 citations and an average annual citation of 49.14; (2) "Rare earth elements: Overview of mining, mineralogy, uses, sustainability and environmental impact" by Ahaque et al., 2014 (Haque et al., 2014) published by Resources with 312 citations and an average annual citation of 34.66.

Keyword Analysis

Further data processing is conducted by showing the author's keywords map. The findings show that there are 774 author keywords obtained from the Governmental Artisanal Mining document, but only the top 132 keywords were taken for analysis, indicating 12 clusters (see Figure 6.).

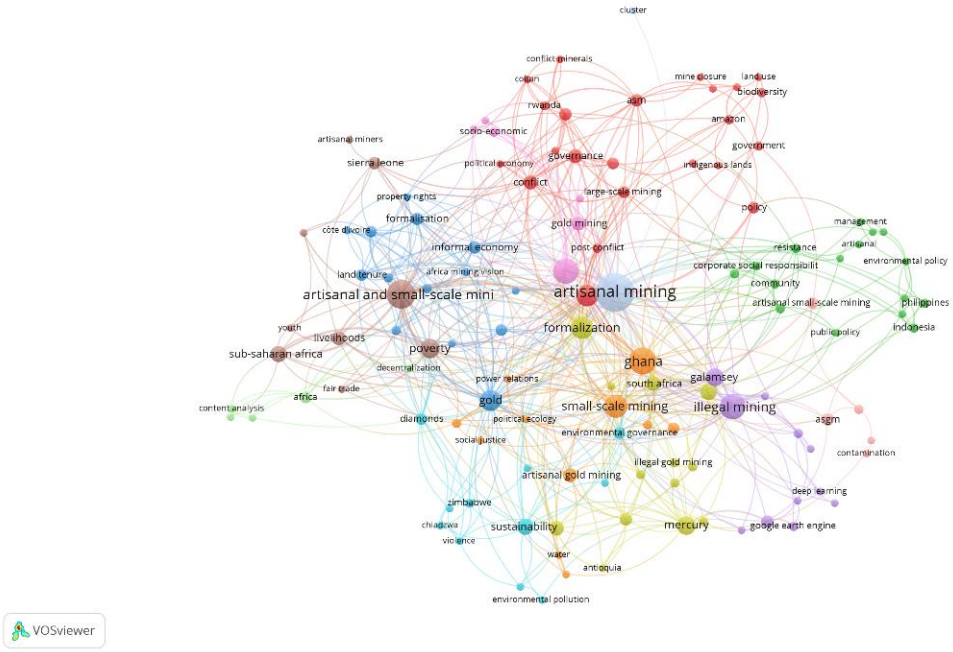


Figure 6. Author keywords

Cluster 1 (red) is characterized by 23 nodes dominated by 7 topics. These topics include mining, conflict, governance, large-scale mining, democratic Republic of Congo, ASM, and policy. Then, these are followed by some other topics: amazon, biodiversity, coltan, communities, conflict minerals, democratic Republic of the Congo, government, indigenous lands, indigenous peoples, land use, *madre de dios*, mine closure, natural resources, political economy, post-conflict, and Rwanda. In cluster 2 (green), there are 16 nodes. Topics in this cluster are dominated by the themes of community, Indonesia, Philippines and corporate social responsibility. Other topics are artisanal, China, development, environmental impact, environmental policy, management, public policy, regulation, resistance, sand mining, small-scale mining, and women. Cluster 3 (blue) is characterized by 14 nodes dominated by 5 topics: gold, informal economy, informality, land tenure, and extractive industries. Other topics are Africa mining, vision, *Burkina Faso*, economic development, formalization, legal pluralism, Liberia, natural resource governance, and property rights. Cluster 4 (yellow) is characterized by 13 nodes. The dominating topics are formalization, mercury, sustainable development, South Africa, and Colombia. In addition, there are also other topics such as abandoned mines, antioquia, artisanal and small-scale gold mining (ASGM), Colombia, environmental conflicts, illegal gold mining, mercury pollution minamata convention on mercury, Peru, and South Africa. Cluster 5 (purple) is characterized by 16 nodes dominated by 4 topics: climate change, risk perception, trust, and expertise. There are also adaptation, disaster communication, fear, framing, journalism, media sociology, mitigation, politics, public opinion, science, television, and uncertainty. Cluster 6 (light blue) is characterized by 11 nodes. The topics are chiadzwa, diamonds, environmental governance, environmental management, environmental pollution, extractive sector, illegal miners, resources, sustainability, violence, and Zimbabwe. Cluster 7 (orange) is characterized by 11 nodes. The topics are artisanal gold mining, Ghana, marginalization, political ecology, pollution, power relations, small-scale mining, social justice, water, water pollution, and water quality. Cluster 8 (brown) is characterized by 9 nodes. The topics include artisanal and small-scale mining, artisanal miners, fair trade, livelihoods, poverty, Sierra Leone, sub-Saharan Africa, sustainable development, and youth. Cluster 9 (in pink) is characterized by 6 nodes dominated by 3 topics artisanal and small-scale mining, capacity building, and gold mining. Furthermore, there are rural, socio-economic, and zamfara. Cluster 10 (in light orange) is characterized by 5 nodes: artisanal small-scale mining, ASGM, contamination, economic, and sustainable mining. Cluster 11 (light green) is characterized by 5 nodes: Africa, content analysis, decentralization, legal consciousness, and mining cooperatives. Cluster 12 (in grey) is characterized by 2 nodes: artisanal mining and cluster.

The next process was to divide these author keywords into three periods to determine the development of the study topic. In Period I (1987-2000), 4 author keywords were found as illustrated in Fıgure 7 and Table 5. The findings present 1 cluster characterized by 4 nodes, consisting of Brazil, consensus building, small-scale mining, and Quary. In this period, there are still very limited topics discussing governmental artisanal mining. Then, in Period II (2001-2010) 92 author keywords were found. The display is presented in Fıgure 8. and Table 5 presenting a diverse study area by creating 9 clusters

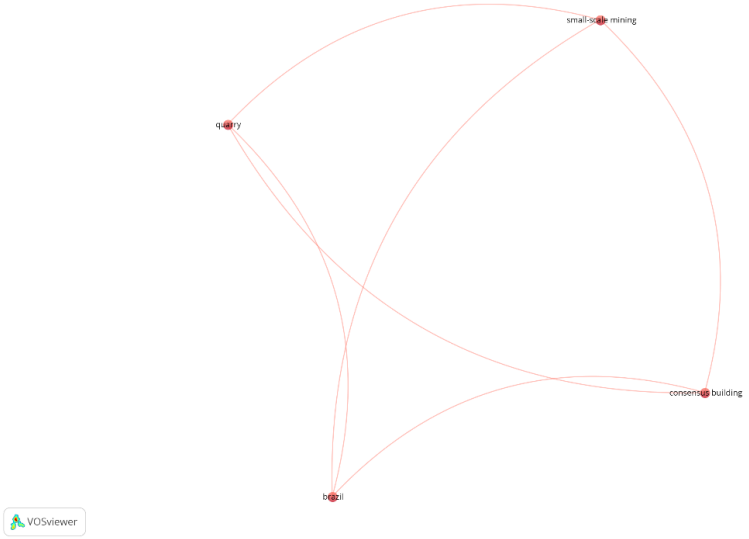


Figure 7. Author keywords in period 1 (1987-2000)

Cluster 1 (red) is characterized by 11 nodes dominated by 2 topics: mining and socio-economic. Then, these are followed by other topics such as dwellers, impact, rural, environmental, income generating activities, gold mining, Geita district, local people, and mining activities. Cluster 2 (green) is characterized by 10 nodes dominated by 2 topics mercury pollution and small-scale mining. Furthermore, there are such topics as processing centres, clean technologies, mineral processing, South Africa, abandoned mines, artisanal mining regulation, artisanal gold mining, and public perception. Cluster 3 (blue) is characterized by 8 nodes dominated by the topic of Regulation. Furthermore, there are Papua New Guinea, environmental effects, China, Asia Pacific, harare guidelines, Philippines, and Indonesia. Cluster 4 (yellow) is characterized by 7 nodes dominated by 2 topics: Ghana and gold. However, there are also other topics such as conflict, livelihoods, fair trade, tropical commodities, and land tenure. Cluster 5 (purple) is characterized by 6 nodes, dominated by the topic of galamsey. This is followed by resistance, development, community, women, and international mining companies.

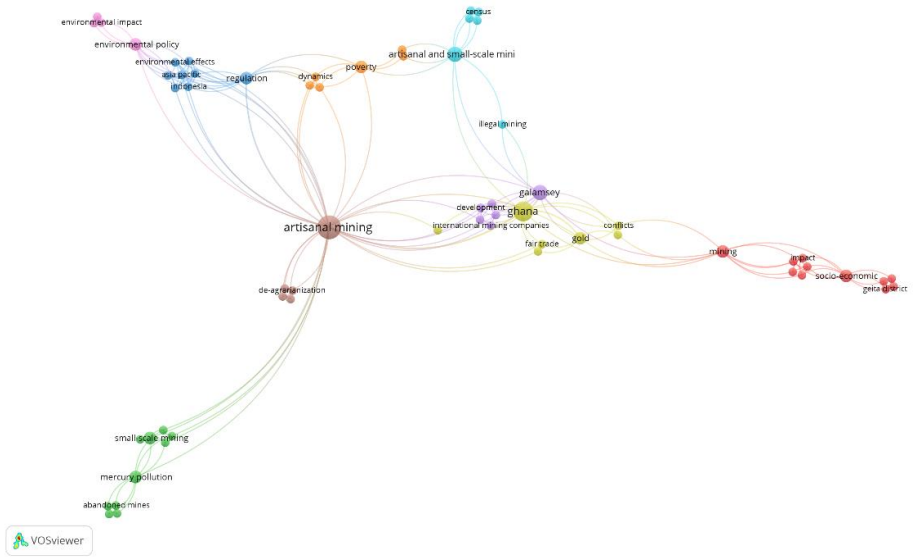


Figure 8. Author keywords in Period II (2001-2010)

Cluster 6 (light blue) is characterized by 6 nodes, dominated by the topic artisanal and small-scale mining. Furthermore, the topics are illegal mining, mercury, developing countries, census, and sustainable livelihoods. Cluster 7 (orange) is characterized by 6 nodes are dominated by the topic of poverty. Other topics include dynamics, minerals, census data, geological information, and tenure. Cluster 8 (brown) is characterized by 5 nodes, dominated by the topic of artisanal mining. Further issues are reagrarianization, deagrarianization, livelihood diversification, and sub-saharan Africa. Cluster 9 (pink) is characterized by 4 nodes are dominated by

the theme of environmental policy. Other issues include environmental impact, management, and small-scale mining. Furthermore, keyword analysis in Period III (2011-2023) found 121 author keywords. Figure 9 presents an increasingly diverse study area by creating 13 clusters.

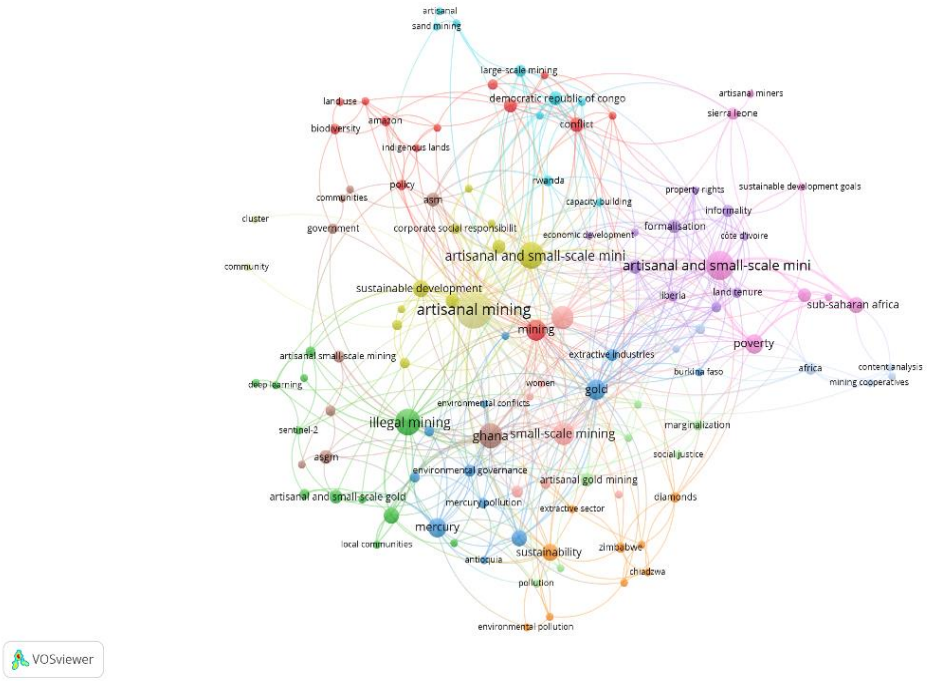


Figure 9. Author keywords in period III (2011-2023)

Cluster 1 (red) is characterized by 13 nodes dominated by 4 studies mining, governance, conflict, and natural resources. Other topics are Amazon, biodiversity, Democratic Republic of Congo, indigenous lands, indigenous people, land use, *Madre de dios*, policy, and political economy. Cluster 2 (green) is characterized by 12 nodes dominated by 3 topics: illegal mining, galamsey and artisanal and small-scale gold mining. Other topics are deep learning, deforestation, environmental management, google earth engine, illegal mining, local communities, remote sensing, resource curse, sentinel-2, and stakeholders. Cluster 3 (blue) is characterized by 12 nodes are dominated by 3 topics: mercury, gold, and Colombia. Then, these are followed by other topics like extractive industries, environmental governance, mercury pollution, Burkina Faso, Antioquia, artisanal and small-scale gold mining (ASGM), environmental conflicts, *minamata* convention on mercury, and post conflicts. Cluster 4 (yellow) is characterized by 10 nodes dominated by 5 topics: artisanal mining, artisanal small-scale mining, sustainable development, gold mining, and South Africa. Other topics are abandoned mines, corporate social responsibility, development, illegal gold mining, Peru, and Zamfara.

Cluster 5 (purple) is characterized by 10 nodes dominated by 3 topics: formalization, informal economy, and informality. Furthermore, there are topics such as Africa mining vision, economic development, land tenure, legal pluralism, Liberia, and property rights. Cluster 6 (light blue) is characterized by 9 nodes dominated by 3 topics Democratic Republic of Congo, large-scale mining, and Rwanda. Then, these are followed by other topics artisanal, capacity building, coltan, conflicts minerals, resistance, and sand mining. Cluster 7 (orange) is characterized by 9 nodes dominated by 3 topics: sustainability, diamonds, and Zimbabwe. Other topics are environmental pollution, extractive sector, illegal miners, resources, and violence. Cluster 8 (brown) is characterized by 9 nodes dominated by 4 topics: Ghana, ASGM, artisanal small-scale mining, and sustainable mining. These are followed by the topics of Indonesia, communities, government, and mine closure. Cluster 9 (pink) is characterized by 8 nodes dominated by 4 topics: artisanal and small-scale mining, poverty, sub-saharan Africa, and livelihoods. These are followed by other topics artisanal miners, Sierra Leone, sustainable development goals (SDGs), and youth. Cluster 10 (light orange) is characterized by 7 nodes dominated by 2 topics: formalization and small-scale mining. Other topics are the Philippines, public policy, water pollution, water quality, and women.Cluster 11 (light green) is characterized by 7 nodes dominated by the topics of artisanal gold mining and marginalization. Other topics are political ecology, pollution, power relations, social justice, and water. Cluster 12 (sky blue) is characterized by 6 nodes dominated by the topic of Africa and natural resource governance. Then, these are followed by other topics such as content analysis, decentralization, and legal consciousness, mining cooperatives. Cluster 13 (light yellow) is characterized by 3 nodes, the topics of which are artisanal mining, cluster, and community.

Table 5. Research topic and list of leading papers

A	B	C	D
Study Area of Governmental Artisanal Mining 1987-2000			
1	4	Brazil, Consensus Building, Quary, and Small-Scale Mining	The stone forum: Implementing a consensus building methodology to address impacts associated with small mining and quarry operations (Peiter et al., 2000)
Study Area of Governmental Artisanal Mining 2001-2010			
1	11	Mining and Socio-Economic	Impacts of mining on income generating activities of rural dwellers in Itesiwaju local government area of Oyo state, Nigeria (Oladeji et al., 2010) The environmental and socio-economic impacts of mining on local livelihoods in Tanzania: A case study of Geita District (Kitula, 2006)
2	10	Mercury Pollution and Small-Scale Mining	Clean artisanal gold mining: A utopian approach? (Hinton et al., 2003) Abandoned artisanal gold mines in the Brazilian Amazon: A legacy of mercury pollution (Veiga & Hinton, 2002)
3	8	Regulation	The dynamics of artisanal and small-scale mining reform (Sinding, 2005) Abandoned artisanal gold mines in the Brazilian Amazon: A legacy of mercury pollution (Veiga & Hinton, 2002)
4	7	Ghana and Gold	Fair trade gold: Antecedents, prospects and challenges (Gavin Hilson, 2008) Strained relations: A critical analysis of the mining conflict in Prestea, Ghana (Gavin Hilson & Yakovleva, 2007)
5	6	Galamsey	Soon there will be no one left to take the corpses to the morgue: Accumulation and abjection in Ghana's mining communities (Bush, 2009) Challenges with eradicating illegal mining in Ghana: A perspective from the grassroots (Banchirigah, 2008) Strained relations: A critical analysis of the mining conflict in Prestea, Ghana (Gavin Hilson & Yakovleva, 2007)
Study Area of Governmental Artisanal Mining 2001-2010			
6	6	Artisanal and Small-Scale Mining	Diamonds, governance and 'local' development in post-conflict Sierra Leone: Lessons for artisanal and small-scale mining in sub-Saharan Africa? (Maconachie, 2009)
7	6	Poverty	The dynamics of artisanal and small-scale mining reform (Sinding, 2005) How has a shortage of census and geological information impeded the regularization of artisanal and small-scale mining? (Gavin Hilson & Maponga, 2004)
8	5	Artisanal Mining	Influence of land tenure practices on artisanal mining activity in Ghana (Nyame & Blocher, 2010) Deagrarianization, reagrarianization and local economic development: Re-orientating livelihoods in African artisanal mining communities (Banchirigah & Hilson, 2010) Fair trade gold: Antecedents, prospects and challenges (Gavin Hilson, 2008) The dynamics of artisanal and small-scale mining reform (Sinding, 2005) Clean artisanal gold mining: A utopian approach? (Hinton et al., 2003) Abandoned artisanal gold mines in the Brazilian Amazon: A legacy of mercury pollution (Veiga & Hinton, 2002)
9	4	Environmental Policy	Opportunities for environmental management in the mining sector in Asia (Burke, 2006) Environmental management of small-scale and artisanal mining: The Portovelo-Zaruma goldmining area, southern Ecuador (Tarras-Wahlberg, 2002)
Study Area of Governmental Artisanal Mining 2011-2023			
1	13	Mining, Governance, Conflict, and Natural Resources	Terr(it)or(ies) of Peace? The Congolese Mining Frontier and the Fight Against "Conflict Minerals" (Vogel & Raeymaekers, 2016)
2	12	Illegal Mining, Galamsey and Artisanal	Zama-Zama mining in the Durban Deep/Roodepoort area of Johannesburg, South Africa: An invasive or alternative livelihood? (Nhlengetwa & Hein,

		and Small-Scale Gold Mining	2015) Socio-demographic factors affecting artisanal and small-scale mining (galamsey) operations in Ghana (Baddianaah et al., 2022) Local perspectives on the adverse environmental effects and reclamation of illegally mined degraded landscapes in North-western Ghana (Baddianaah et al., 2023) Impact of the ban on illegal mining activities on raw water quality: A case-study of Congo water treatment plant, Ashanti region of Ghana (Bawa et al., 2022) A review from environmental management to environmental governance: paradigm shift for sustainable mining practice in Ghana (Li et al., 2021)
3	12	Mercury, Gold, and Colombia	Territorial peace and gold mining in Colombia: local peace building, bottom-up development and the defence of territories (Le Billon et al., 2020) Contested diamond certification: Reconfiguring global and national interests in Zimbabwe's Marange fields (S. J. Spiegel, 2015a) Managing artisanal and small-scale mining in forest areas: Perspectives from a post-structural political ecology (HIRONS, 2011)
4	10	Artisanal Mining, Artisanal Small-Scale Mini, Sustainable Development, Gold Mining, and South Africa	Corporate social responsibility and artisanal mining: Towards a fresh South African perspective (Bester & Groenewald, 2021) Artisanal and Small-Scale Mining as a challenge and possible contributor to Sustainable Development (Zvarivadza, 2018) Resolving artisanal and small-scale mining challenges: Moving from conflict to cooperation for sustainability in mine planning (Zvarivadza & Nhleko, 2018)
Study Area of Governmental Artisanal Mining 2011-2023			
5	10	Formalisation, İnformal Economy, and İnformality	Going for gold: Transitional livelihoods in Northern Ghana (Gavin Hilson et al., 2013) Industry approach to the conflict minerals legislation (Connors, 2012)
6	9	Democratic Republic of Congo, Large Scale Mining and Rwanda	Artisanal copper mining and conflict at the intersection of property rights and corporate strategies in the Democratic Republic of Congo (Katz-Lavigne, 2019) Addressing the capacity building challenge in the mining sector in Rwanda: The implications of Rwanda's 2014 mining and quarry law (Nwapi, 2017)
7	9	Sustainability, Diamonds, and Zimbabwe	Formal mining investments and artisanal mining in southern Madagascar: Effects of spontaneous reactions and adjustment policies on poverty alleviation (Canavesio, 2014)
8	9	Ghana, ASGM, Artisanal Small-Scale Mining, and Sustainable Mining	Informal artisanal and small-scale gold mining (ASGM) in Ghana: Assessing environmental impacts, reasons for engagement, and mitigation strategies (Achina-Obeng & Aram, 2022) Planning for the effective and sustainable management of Ghana's artisanal small-scale gold mining industry (Wireko-Gyebi et al., 2022) Narrowing the gap between local standards and global best practices in bauxite mining: A case study in Malaysia (Kuan et al., 2020)
9	8	Artisanal and Small-Scale Mini, Sub-Saharan Africa, and Livelihoods	The ‘Zambia Model’: A blueprint for formalizing artisanal and small-scale mining in sub-Saharan Africa? (Gavin Hilson, 2020) Poverty, Artisanal and small-scale mining (ASM) in sub-Saharan Africa: Re-conceptualizing formalization and ‘illegal’ activity (Gavin Hilson et al., 2017) Ethical minerals: Fairer trade for whom? (Gavin Hilson et al., 2016) Artisanal gold mining and rural development policies in Mozambique: Perspectives for the future (Dondeyne & Ndunguru, 2014)
10	7	Formalization and Small-Scale Mining	Innovation for sustainable development in artisanal mining: Advances in a cluster of opal mining in Brazil (Milanez & Puppim de Oliveira, 2013)
11	7	Artisanal Gold Mining and Marginalization	Digging for Gold or Justice? Misrecognition and Marginalization of “Illegal” Small-Scale Miners in Ghana (Ofori & Ofori, 2018) Zama-Zama mining in the Durban Deep/Roodepoort area of Johannesburg, South Africa: An invasive or alternative livelihood? (Nhlengetwa & Hein, 2015)
12	6	Africa and Natural	Formalization as Development in Land and Natural Resource Policy (Putzel et

		Resource Governance	al., 2015)
13	3	Artisanal Cluster and Community	Mining, Application of MCDM in evaluating emerging technology for artisanal mining

Information:
A = Cluster,
B = Number of Nodes,
C = Area of Research Focus, and
D = Lead Papers in Terms of Total Link Strength

To see the development of the topic of study on governmental artisanal mining, a summary is also presented in the form of topics and literature references per period. Through this mapping of literature studies, future researchers or writers are expected to get a reference in developing study topics and literature, they will refer to. Table 5 summarizes the topics of publication and the leading literature.

According to the author's keywords, the dominant topic is artisanal and small-scale gold mining, with studies on environmental issues, especially the impact of mercury, and its impact on socio-economic conditions and conflict. Morante-Carballo et al. (2022) also clarifiedit through mapping four areas of study on artisanal and small-scale mining related to social condition factors, environmental and health impacts of mercury, and mining as an alternative livelihood. This provides an opportunity for other topics such as types of artisanal mining other than gold, other global south countries, as well as political and resource issues including the identity of local communities, to be researched further given the limited discussion of these topics. In addition, the concept of "governmentality" has not been widely discussed by the authors. There is an opportunity for qualitative research studies to explain further the concept of governmentality from various perspectives, for example, critical social studies can use Michael Foucault's concept of power (Burchell et al., 1993; Ettlinger, 2011; Larner & Walters, 2004).

The study of artisanal and small-scale gold mining is an issue that has long attracted the interest of not only publications in the Scopus database but also Galvin Hilson as an author (Hilson, 2005; Hilson, 2005b, 2005a, 2006, 2016b, 2018a, 2018b, 2020, 2021; Hilson et al., 2017, 2019, 2020; Hilson & Banchirigah, 2009; Hilson & Maconachie, 2017; Hilson & Mcquilken, n.d.). This can be seen through a number of his publications. Bibliometric literature studies still using the concept of artisanal and small-scale mining as one of its variables tend to continue to refer to Galvin Hilson as one of the influential authors (Sununianti & Nugroho, 2023). We noticed that there is a positive relationship between topics, influential authors, countries, and publishers regarding the theme of governmental artisanal mining. The theme of artisanal and small-scale mining tends to be the focus of author Galvin Hilson's studies. Coming from the United Kingdom, he does not encounter any significant obstacles in conducting research, development, or publication. Moreover, the global north country also has more resources for publishing reputable research. Thus, networking in collaborative writing or research becomes an added value difficult to compare with authors from countries in the global south.

This bibliometric study is very supportive of mapping literature studies during the COVID-19 pandemic. The abundance of metadata can be an opportunity and clue to conduct further research or mentoring activities. Artisanal and small-scale mining studies related to the COVID-19 pandemic are still very limited. Kyaw et al. (2021) discuss health assessment tools as a reference for future health assessments using a transdisciplinary approach and online method. Hilson (2021) explained that the impact of the COVID-19 pandemic on the ASM community in Africa has helped shape self-organization and adaptation to the effects of lockdown measures and reduced productivity due to reduced mobility of labour, capital, and equipment due to disconnection from international markets. This moment has revived discussions about ASM as an important livelihood in Africa that is not immune to the shocks of Covid-19, making it important to define the role of this sector in regional development. However, the direct relationship between artisanal mining practices and COVID-19 pandemic has not been reviewed or published in the Scopus database.

Conclusion

This mapping of literature study shows that the topic of governmental artisanal mining has developed significantly since 2008 until now. Generally, the publications are scientific articles and the majority have been indexed by Scopus. The field of study tends to be in the aspect of social science and commonly discussed topics around artisanal and small-scale gold mining that have an impact on social life, health, and the environment. Galvin Hilson is reputable to remain to be an impactful author with the "artisanal mining" being the search keyword . Global north countries tend to dominate publications and networking on similar topics, while global

south countries tend to have limited objects of study or places where the practice of artisanal and small-scale gold mining takes place.

Future studies can complement this study with field research raising issues from the social critical perspective of resource governance, local politics, and local community values including other types of artisanal mining. In addition, further bibliometric studies can also complement it by using other data sources, combined data processing, or using other software. Thus, the limitations of distance and physical environment, such as the outbreak of the COVID-19 pandemic will notbe a barrier to research development.

Scientific Ethic Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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