Environmental Forensic Research: Systematic Literature Review and Bibliometric Analysis

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Abstract

This study examines the changing field of environmental forensic studies between 2014 and 2023. The study utilises a rigorous technique to systematically analyse the literature and conduct a bibliometric analysis to quantify and map the intellectual structure of the topic. The goals encompass the analysis of citation patterns, authorship networks, collaboration trends and identifying significant contributors, countries, journals, and publishers. The study employs the Scopus database to identify 33 documents from 10,117 pertinent papers. The United Kingdom exhibits the highest research output, followed by Australia, Colombia, France, and the United States. One can identify influential authors such as Pringle, J.K., by analyzing citation trends and notable works like Roux's trace evidence examination. Co-occurrence maps are used to investigate keyword patterns, unveiling groupings centered on terms such as "controlled study," "forensic science," and "geology." The emerging terms indicate the development of research fields such as disappearance, era, and training. The study thoroughly examines environmental forensic research trends, providing significant insights for academics, professionals, and decision-makers. The work highlights the vital importance of environmental forensics in tackling present-day environmental issues. The findings enhance comprehension of the discipline, assisting in guiding future research paths and highlighting the importance of prominent journals like "Forensic Science International" and the "Journal of Forensic Sciences" in spreading influential research.

Keywords: Environmental Forensic; Systematic Literature Review; Bibliometric Analysis

1. Introduction

Environmental forensics is an interdisciplinary domain that integrates scientific, legal, and investigative methodologies to detect and resolve instances of environmental pollution and criminal activities (Boehm & Murphy, 2015; Ghaly, 2018; Spikmans, 2015). The process entails gathering, scrutinising, and deciphering evidence to ascertain the culpable entity, timeframe, and magnitude of contamination (Brčeski & Vaseashta, 2021; Spikmans, 2015). Environmental forensic investigations play a vital role in legal procedures and can assist in establishing factual evidence related to potential disputes (Ghaly, 2018). The discipline of Environmental Forensic Research has significantly contributed to sustainable environmental stewardship in recent years. This contribution is characterised by the intersection of scientific progress, changes in legislation, and growing environmental concerns. As the intricate relationship between human actions and

their environmental effects becomes more evident, there is a growing demand for rigorous research approaches.

Environmental forensic research has grown significantly from 2014 to 2023. The prominence of environmental forensics has increased as global worries regarding environmental deterioration, pollution, and the influence of human activities on ecosystems have intensified. The ever-changing nature of environmental concerns necessitates inventive and flexible approaches to studying and resolving them. Environmental forensics has arisen to address this need, combining scientific concepts with legal frameworks to discover, evaluate, and alleviate environmental pollution. Rapid scientific advancement, increased environmental awareness, and a growing focus on interdisciplinary cooperation characterize the period between 2014 and 2023 as a turning point in the field's development.

The subject of environmental forensic research has had substantial growth in recent years. Conducting a thorough literature review and bibliometric analysis from 2014 to 2023 might offer vital insights into this domain's progress and research patterns. A bibliometric analysis conducted on microbial forensics publications from 1984 to 2022 demonstrated a steady growth in the number of research papers in this field. The analysis also identified the most prolific sources of publications and highlighted the significant contribution of the "Journal of Forensic Sciences" in generating research outputs (Guo et al., 2023). A different study performed a bibliometric analysis of the research on environmental regulation's influence on the advancement of green technology. It examined the current state of research and identified trends in the field of research and development in this domain (Li et al., 2022). A search on Scopus using the term "forensic science" revealed that most of the content in this area comes from the Global North; this shows the importance of understanding the challenges of providing long-term forensic science services (Bouzin et al., 2023a).

The motivation for this research arises from the necessity to conduct a comprehensive literature review to consolidate current knowledge, pinpoint areas where further study is needed, and obtain a deeper understanding of the thematic progression within the topic. Concurrently, bibliometric analysis aims to measure the intellectual framework of environmental forensic research and offer a comprehensive perspective of the scholarly terrain. This research aims to investigate environmental forensic investigations throughout the chosen time using a thorough systematic literature review and a detailed bibliometric analysis.

Systematic Literature Review (SLR) is a method that enables gathering pertinent information related to a specific issue based on predetermined criteria for eligibility. This procedure aims to answer the research questions that have been created. Systematic literature review (SLR) distinguishes itself from typical narrative reviews by employing a replicable, scientific, and transparent approach. To address a given research subject, gathering all relevant papers and materials that meet our predetermined criteria for inclusion is beneficial. It employs precise and methodical protocols to reduce the likelihood of bias while conducting searches, identifying, evaluating, combining, analysing, and summarising studies (Mengist et al., 2020). When the technique is executed accurately and with low error, the study can yield dependable data and conclusions that can assist decision-makers and scientific practitioners take appropriate actions

(Antman et al., 1992; Oxman & Guyatt, 1993; Tranfiel et al., 2003). A well-executed strategy for the SLR process is crucial, as it guarantees meticulous planning prior to commencing the actual review activity.

Bibliometrics is the application of quantitative techniques to analyse scholarly publications (Nicolaisen, 2009). Bibliometric processes, sometimes called "analysis," are widely recognised as established scientific disciplines and integral parts of research evaluation methodology, especially in scientific and practical fields (Ellegaard & Wallin, 2015). This approach is essential and practical for determining and analyzing the advancement of a study field (Li et al., 2022). Bibliometric analysis is a rigorous statistical method that comprehensively investigates publications and patterns within a particular scientific field. This study aims to identify countries and writers who have had a significant influence and to assess the current research directions (Guo et al., 2023). It identifies the publications by authors, the annual count of published articles, an analysis of the most frequently published journals, an analysis of the top countries based on the number of published documents, an analysis of the most prolific authors, an analysis of the most cited articles, an analysis of the co-occurrence of keywords, and an analysis of the trending topics (Guo et al., 2023).

This systematic literature review and bibliometric analysis are meant to find out how different studies are in environmental forensics and to look at the research trends in this area from 2014 to 2023. The research inquiries employed in this investigation are as follows:

RQ1: What are the prevailing patterns in publications regarding environmental forensics?

RQ2: What is the citation trend in environmental forensics?

RQ3: What is the country's contribution to the research of environmental forensics?

RQ4: What is the contribution of publishers to environmental forensic?

RQ5: What is the contribution of authors to environmental forensic?

RQ6: What are the most frequently utilised keywords in research?

RQ7: What are keywords in research trends?

2. Method

The study conducted a thorough systematic literature review and bibliometric analysis using the Scopus database. The Scopus database is an extensive database that provides access to relevant publications spanning multiple scientific areas and a curated database consisting of high-quality publications. The environmental forensic field data were collected from the Scopus Main Collection on December 7, 2023. The research protocol utilised the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) guidelines. The selection process has four stages: identification, screening, eligibility, and inclusion (Liberati et al., 2009; Moher et al., 2009). The researchers employed the term "environmental forensic" to make identifications by searching the Scopus database. The following keywords were inputted into the Scopus web search:

“Environmental Forensic”. This query can be written as ALL ("Environmental Forensic") AND PUBYEAR > 2014 AND PUBYEAR < 2023 AND (LIMIT TO (SUBJ-AREA, "MEDI") OR LIMIT-TO (SUBJAREA, "BIOC") OR LIMIT-TO (SUBJAREA, "PHAR") OR LIMIT-TO (SUBJ-AREA, "IMMU") OR LIMIT-TO (SUBJ-AREA, "HEAL)) AND (LIMIT TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (EXACTKEYWORD, "Forensic Science")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (OA, "all")) in the form of Boolean search.

The first search yielded a total of 13,243 documents. However, after narrowing down the search to include just articles published between 2014 and 2023, 10,117 documents were found. In the subsequent phase, known as screening, the researcher established specific criteria for inclusion. These criteria encompassed the following:

a. The subject area of publications must pertain to medicine, biochemistry, genetics and molecular biology, pharmacology, toxicology and pharmaceutics, or immunology and microbiology (depicted in Figure 1).
b. Publications must take the form of articles.
c. Publications must be written in English.
d. The keywords must be related to “forensic science”.
e. The papers must be limited to open-access publications.

After a thorough screening, we selected 33 publications that met the specific criteria. The final step involved examining the manuals, titles, and abstracts of the 33 publications. Subsequently, the study employs descriptive analysis and bibliometric analysis to investigate publication patterns related to environmental forensics. The data used for this analysis is gathered from the Scopus database and transferred to the VOSviewer software. The VOSviewer study yielded a visualisation of the interconnected keywords derived from the 33 key papers.

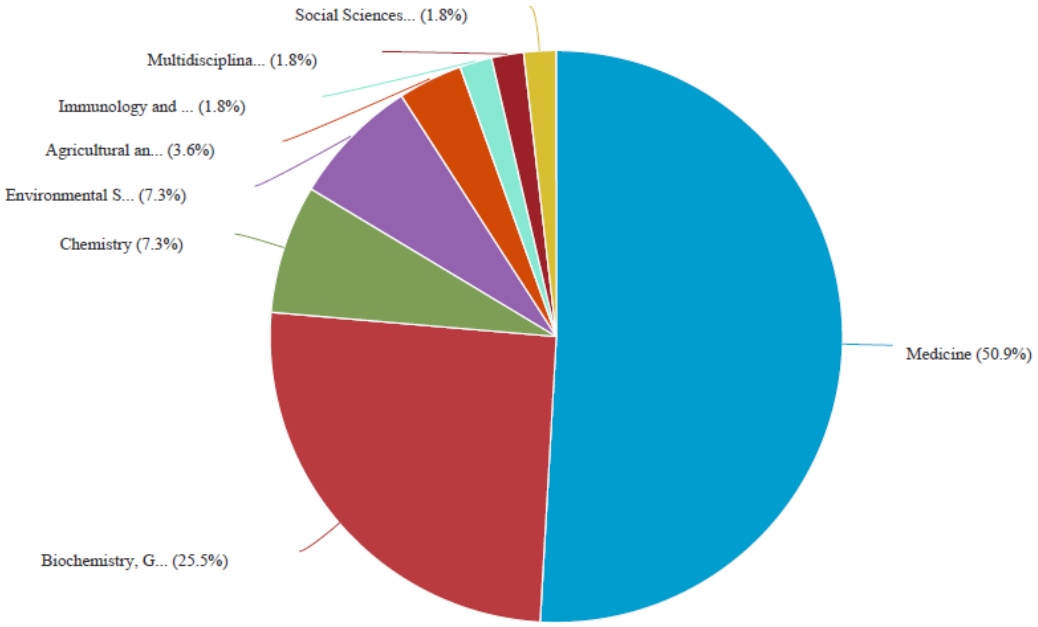

Figure 1. Subject area of publications

The data that satisfies the specified criteria for inclusion and completes the four stages of the PRISMA process will then undergo analysis using various software applications, such as Microsoft Excel, Publish or Perish, and Vosviewer. Microsoft Excel is utilized to analyze the temporal pattern of publications about environmental forensics from 2014 to 2023 and assess the distribution of journal publications based on quartile values. The Publish or Perish tool is used to determine the researcher's yearly citations, compute the cumulative citations from the annual publications, and calculate the values of the h-index and g-index. The VOSviewer software is utilised to examine the patterns of relationships between countries in the field of environmental forensic research, as well as to identify research emphasis and innovation. The assortment of objects is illustrated in Figure 2, as shown below.

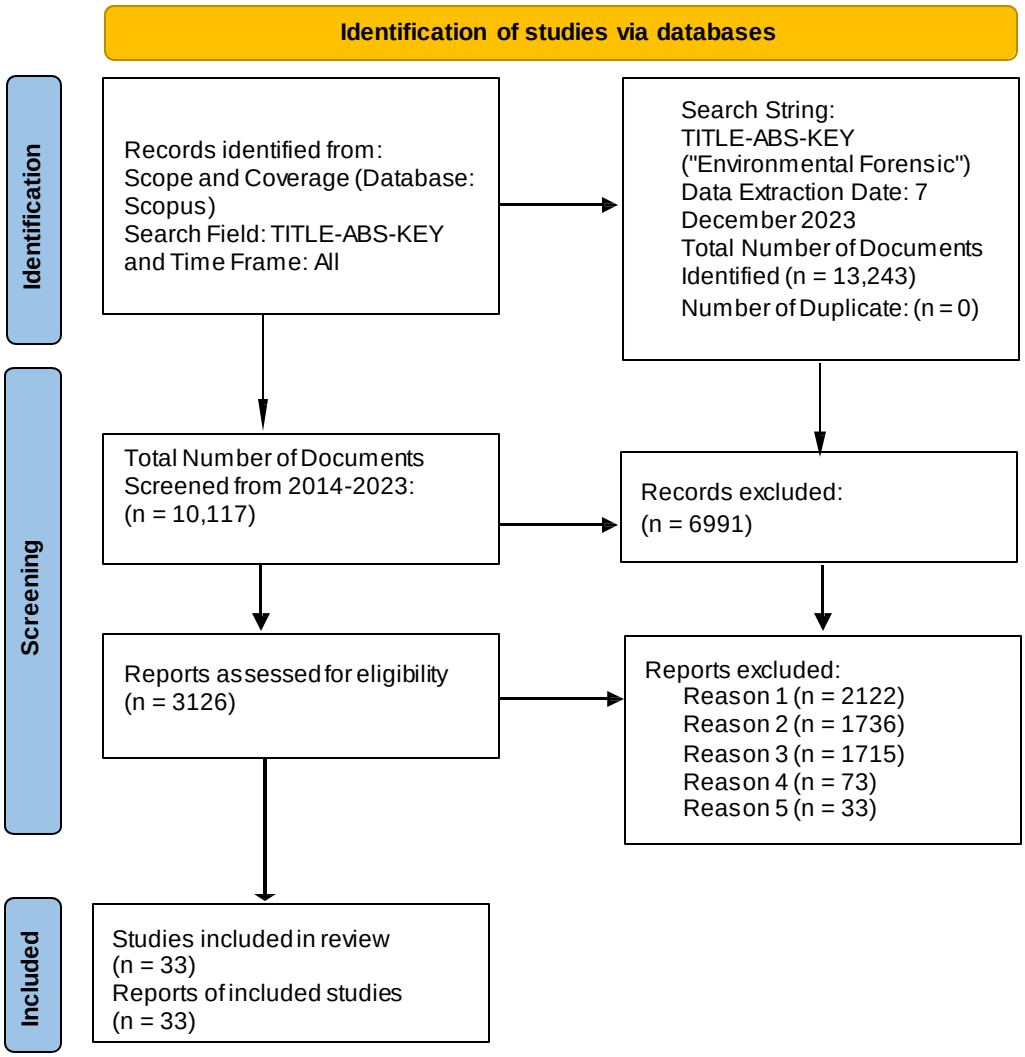

Figure 2. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases for Environmental Forensic.

3. Result and Discussion

A thorough literature review and bibliometric analysis were conducted on 33 publications in the field of environmental forensic, collected between 2014 and 2023, that fit the specified criteria. Further analysis will be conducted on publication patterns, citation trends, nation and journal distribution, and research focus.

Prevailing patterns in publications regarding environmental forensic

Figure 3 below categorizes 33 publications based on their year of publication and illustrates the chronological development of publication research from 2014 to 2023.

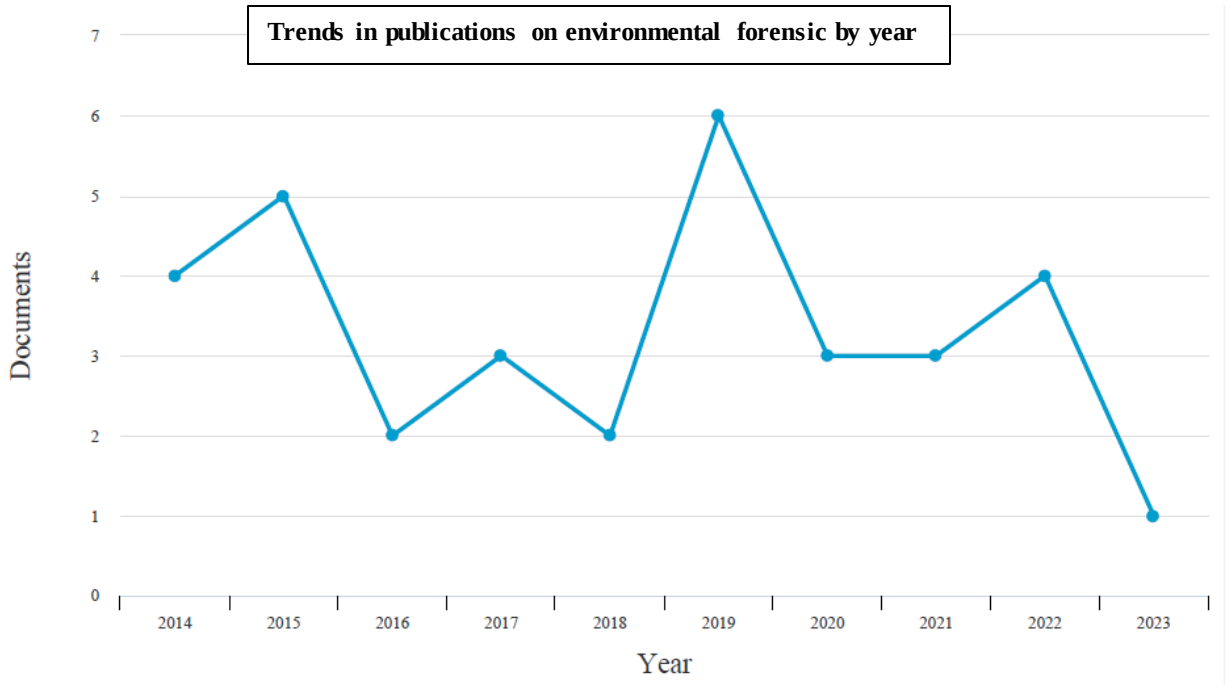

Figure 3. Displays the trends of studies based on the year of publication.

Figure 3 demonstrates a steady rise in publications about environmental forensic from 2014 to 2023, with minimal variation observed between 2022 and 2023. In 2019, there was a significant growth of 18.18%. However, from 2020 to 2021 and from 2022 to 2023, there were consecutive reductions. In 2015, there were five publications on environmental forensics, which increased to six by 2019. There has been a significant increase in research on environmental forensics (Bouzin et al., 2023a).

Citation trend in environmental forensic

Figure 4 depicts the patterns of citations related to environmental forensic between 2014 and 2023. Regarding publication patterns, 33 articles were gathered according to their publication year. These publications will be further analysed regarding the overall number of publications per year, as depicted in Figure 4 below.

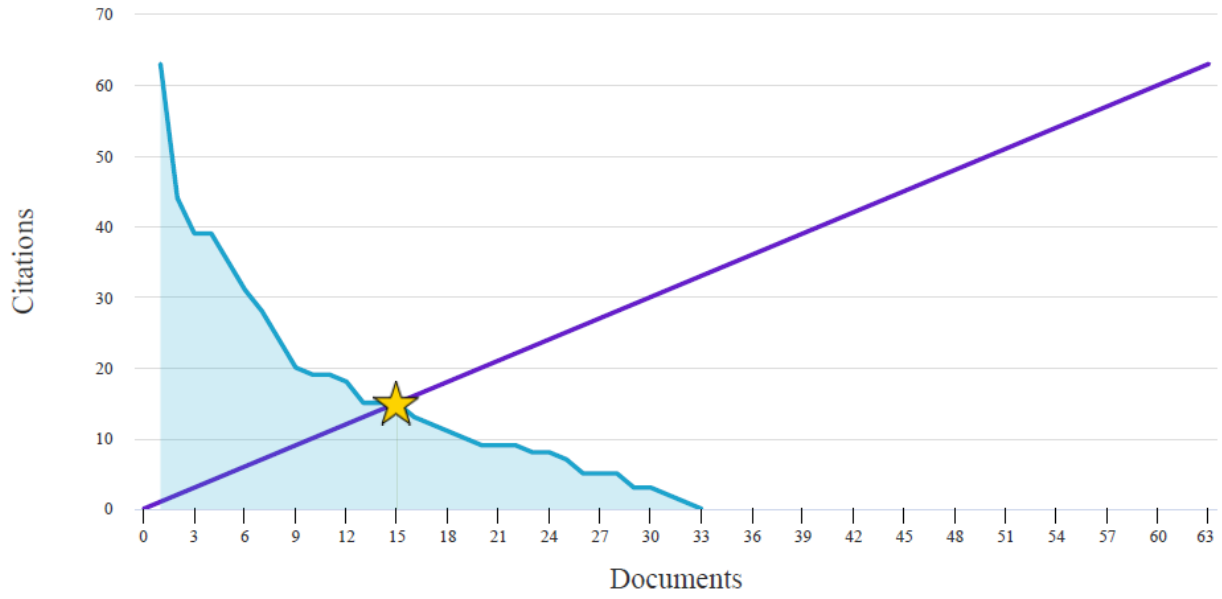

Figure 4. Citation of Publications, a citation overview for a set of 33 documents (h-index = 15 (Of the 33 documents considered for the h-index, 15 have been cited at least 15 times).

In this investigation, 33 referenced out of 1561 were found to have a minimum of 8 citations. These references were cited three times in each of 3 papers (Van Eck & Waltman, 2010). The network visualisation map of these references is depicted in Figure 5, while Table 1 presents the cited articles and authors' names (see Appendix I for the full list).

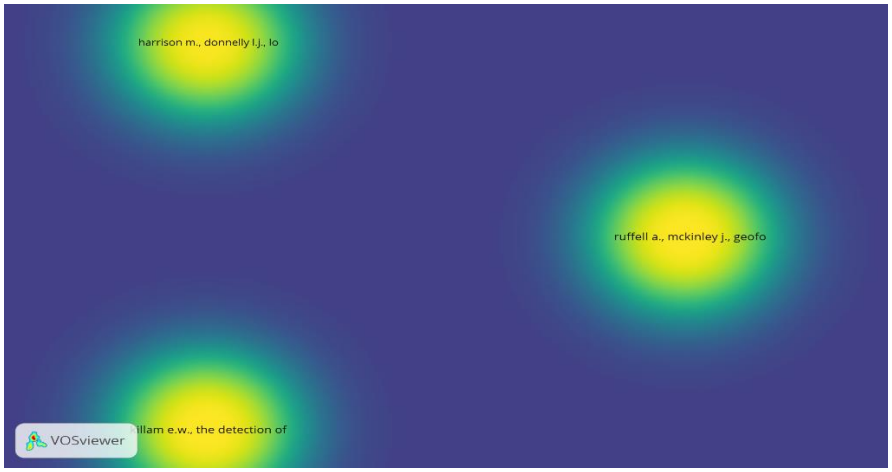

Figure 5. The Density Visualization Map of the 'Document' Co-citation Analysis.

Table 1 Presents the results of the citation analysis conducted on the publications.

Document	Citation	Link	Year	CitesPerYear	CitesPerAuthor
roux (2015)	63	0	2015	7.88	13
khodakova (2014)	44	0	2014	4.89	9
fernandez-alvarez (2016)	39	0	2016	5.57	8
yao (2015)	39	0	2015	4.88	6
scott (2014)	36	0	2014	4	9
pringle (2016)	31	0	2016	4.43	4
evers (2018)	28	1	2018	5.6	14
smith (2014)	24	0	2014	2.67	3
pringle (2015b)	20	0	2015	2.5	3
pringle (2015a)	19	0	2015	2.38	3
retief (2014)	19	0	2014	2.11	6
young (2021)	18	0	2021	9	9
molina (2020)	15	2	2020	5	3
de Figueiredo (2019b)	15	1	2019	3.75	3
boegelsack (2021)	15	0	2021	7.5	3
irlam (2020)	13	0	2020	4.33	2
procopio (2020)	12	0	2020	4	2
gallidabino (2019)	11	0	2019	2.75	2
de caritat (2019)	10	0	2019	2.5	3
mcculloch (2017a)	9	0	2017	1.5	2
mcculloch (2017b)	9	0	2017	1.5	3
rubio-melendi (2018)	9	0	2018	1.8	1
wisniewski (2019)	8	0	2019	2	1
xia (2015)	8	0	2015	1	2
pringle (2022)	7	0	2022	7	1
bolton-king (2022)	5	0	2022	5	2
de Figueiredo (2019a)	5	1	2019	1.25	1
jones (2021)	5	0	2021	2.5	5
wilks (2017)	3	0	2017	0.5	1
molina (2022b)	3	2	2022	3	0
blakey (2019)	2	0	2019	0.5	1
molina (2022a)	1	1	2022	1	0
martin (2023)	0	0	2023	0	0

In addition, among the 737 published sources, 33 were identified as having a minimum of 20 references. Each source contained eight references mentioned uniquely across the eight publications (Van Eck & Waltman, 2010). The network visualisation map of these sources is depicted in Figure 6, while Table 2 presents the eight most frequently referenced sources.

Figure 6. The Network Visualization Map of the 'Sources' Co-citation Analysis

Table 2. The 8 Most Cited Sources

No	Source	Citations	Total link strength
1	forensic sci. int.	97	1153
2	j. forensic sci.	74	960
3	forensic sci int	88	956
4	j forensic sci	73	926
5	criminal and environmental soil forensics	21	389
6	sci. justice	26	382
7	environ. forensics	20	252
8	plos one	21	236

Roux (2015) did a study titled "The end of the (forensic science) world as we know it? An example of trace evidence." The article discusses trace evidence, which has received the maximum number of citations, precisely 63 times. The prevailing notion of forensic science as a collection of many fields primarily aiding the criminal justice system (referred to as forensics) is currently facing a crisis or, at the very least, exhibits several abnormalities and significant constraints. Various commentators have extensively explored the symptoms of the problem in recent years, with the 2009 study by the US National Academies of Sciences (NAS 2009: Strengthening Forensic Science in the United States: A Route Ahead) serving as a clear example. While recognized as necessary, the widespread implementation of more rigorous business models in forensic science casework and the growing number of normative and compliance procedures add stress to an

already struggling discipline and further divide the various tasks within forensic science. The NAS report and other similar reviews have criticised this fragmentation. One can question whether these problems are not merely a consequence of an inadequate paradigm. If this is the situation, the existing challenges encountered by forensic science might foreshadow substantial transformations in the field. This presentation emphasises trace evidence, a crucial aspect of forensic science due to its significance in terms of epistemology and history, to foster a more extensive discussion. Undoubtedly, this area is facing a global siege today. The present and forthcoming obstacles trace evidence encounters are deliberated, along with a few potential solutions. The current circumstances provide significant prospects to redefine trace evidence and forensic science completely. Ultimately, a unique, more robust, and more dependable scientific field may develop by reevaluating the current approach to forensics, reconsidering the core concepts of forensic science, and modifying them to fit the demands of the modern era (Roux et al., 2015). The second-highest number of citations is for Khodakova's (2014) research. This study looks at how well random whole metagenomic sequencing can tell the difference between similar soils from two cities for use in forensic science. Multiple samples were obtained from two parklands in residential neighborhoods roughly 3 km apart, and the DNA was subsequently extracted. They used shotgun sequencing, whole genome amplification (WGA), and single arbitrarily primed DNA amplification (AP-PCR) to make the soil metagenomic profiles. They added more information to the full and reduced metagenomic datasets using the M5NR and M5RNA databases to put organisms into taxonomic groups and the SEED Subsystems databases to put metabolisms into metabolic groups. Scientists used various statistical tools to compare more things. Hierarchical agglomerative clustering (CLUSTER), similarity profile analysis (SIMPROF), non-metric multidimensional scaling (NMDS), and canonical analysis of principal coordinates (CAP) were some of these models. They did this at all critical levels of metabolic and taxonomic classification. Our data indicated that both shotgun and WGA-based methods produced metagenomic profiles for the soil samples that were remarkably similar, making it difficult to differentiate between the models reliably. A practical AP-PCR method was used to acquire consistent metagenomic DNA profiles at specified sites. These profiles were then used to distinguish visually similar soil samples from two locations accurately.

Countries' contribution to the research of environmental forensic

Out of the 16 countries cited, both developed and developing nations have published research on environmental forensic, as long as the article is identified correctly. The data indicate that United Kingdom countries produce about 63.63% of the environmental forensic recovery publications, highlighting the leadership position of the United Kingdom's academic discipline in this sector. Nevertheless, most of the top 10 countries were established nations, including Australia, Colombia, France, and the United States, among the list's developing countries. The United Kingdom is the most significant contributor, accounting for 21 papers out of all the articles published. Australia follows with four documents, or 12.12% of the total. Colombia, France, and the United States each have three papers, accounting for 9.09% each (refer to Figure 7).

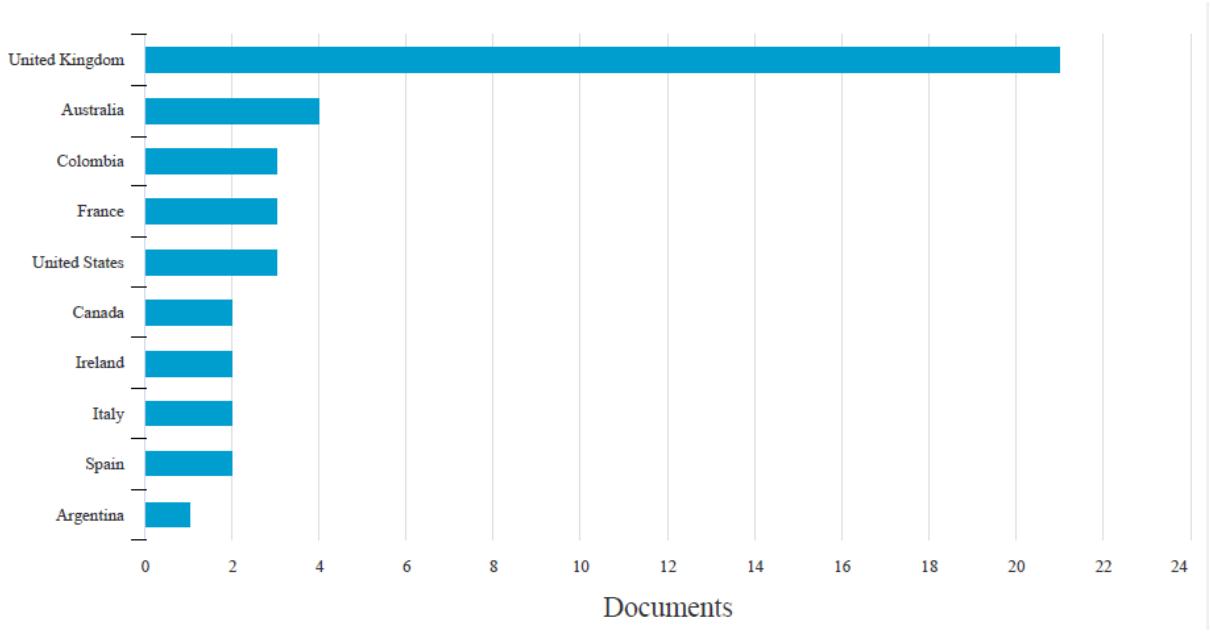

Figure 7. Top 10 Countries on Environmental Forensic

The UK and Australia are the dominant countries in environmental forensic research since they have the highest number of primary authors, publications, and most-cited articles. Moreover, Canada, Ireland, Italy, and Spain are the leading countries in America and Europe in terms of publications on environmental forensics, each having two papers, surpassing all other countries. South Africa has the most publications within its geographical region, specifically Africa (Bouzin et al., 2023a). Nevertheless, based on this statistic, South Africa does not make it into the top ten with this figure.

Developed and developing countries contribute distinct research contributions across the most critical research domains outlined in our findings. Developed countries generate scientific information due to their dominant position in significant publishers and publications, like the UK, Australia, European countries, and the USA (Blakey et al., 2019; Bolton-king et al., 2022; Bouzin et al., 2023a, 2023b; Evers & Masters, 2018; Figueiredo, Bouveresse, et al., 2019; Figueiredo, Cordella, et al., 2019; Finley et al., 2020; Gallidabino et al., 2019; Irlam et al., 2020; Jones, 2021; Mcculloch, Dawson, et al., 2017; Mcculloch, Morgan, et al., 2017; Pringle et al., 2022; Roux et al., 2015; Spikmans, 2015; Wilks et al., 2017; Young & Linacre, 2021). Research in developing countries is ongoing (Brčeski & Vaseashta, 2021; Martín et al., 2022; War et al., 2018; Yao et al., 2015). Researchers need help when selecting a research topic and formulating a research statement. Furthermore, researchers need help with expansion, shortcomings in infrastructure, funding constraints, etc. Only a few publications, writers, or journals originate from underdeveloped nations. Argentina has been recognised as one of the top ten countries in this survey. Previous studies have indicated that European governments have exhibited a keen inclination towards environmental forensic investigation (Roux et al., 2015).

Contribution of Publishers to Environmental Forensic

The International Journal of Environmental Research and Public Health is one of the several journals that publish studies on environmental forensic. The expansion of this area has led to the establishment of a substantial array of academic resources, such as specialised publications, that are accessible to scholars. Notable examples include the Journal of Forensic Sciences, Australian Journal of Forensic Sciences, and Forensic Science International. In addition, theoretical frameworks in environmental forensic research are progressively employed to elucidate certain phenomena (Brčeski & Vaseashta, 2021; Figueiredo, Bouveresse, et al., 2019; Jones, 2021; Roux et al., 2015). Therefore, researchers submitted publications in different environmental forensic journals to elucidate the observed findings in their studies. Figure 8 illustrates the top five journals that are both very productive and prominent in various domains. various journals can be utilised for the purpose of categorising other journals and their publications. The journal data is arranged according to their productivity.

Thirty-three papers about the subject were identified, all published across 14 different academic journals. The journal that demonstrated the highest level of productivity is "Forensic Science International," which accounted for 30.30% of the articles in the collected sample. It was closely followed by the "Journal of Forensic Sciences" at 24.24%. Other journals that contributed significantly include "The Australian Journal of Forensic Sciences," "The International Journal of Environmental Research and Public Health," and "The Journal of Chromatography A," each publishing 6.06% of the articles. The remaining journals, namely "Analytica Chimica Acta," "Chemosphere," "Forensic Science International Genetics," "Forensic Science International Reports," "Frontiers in Microbiology," "Journal of Forensic Science And Medicine," "Philosophical Transactions of The Royal Society B Biological Sciences," "Plos One," and "Science And Justice," each published 3.03% of the articles. Figure 8 displays the anticipated leading journals and prestigious publishers in recovery in sports nutrition. Forensic Science International is the primary publication venue for most of these publications, indicating that each author selects this magazine to publish their work. Alternatively, specific individuals like the Journal of Forensic Sciences, a publication with articles spanning several multidisciplinary scientific domains.

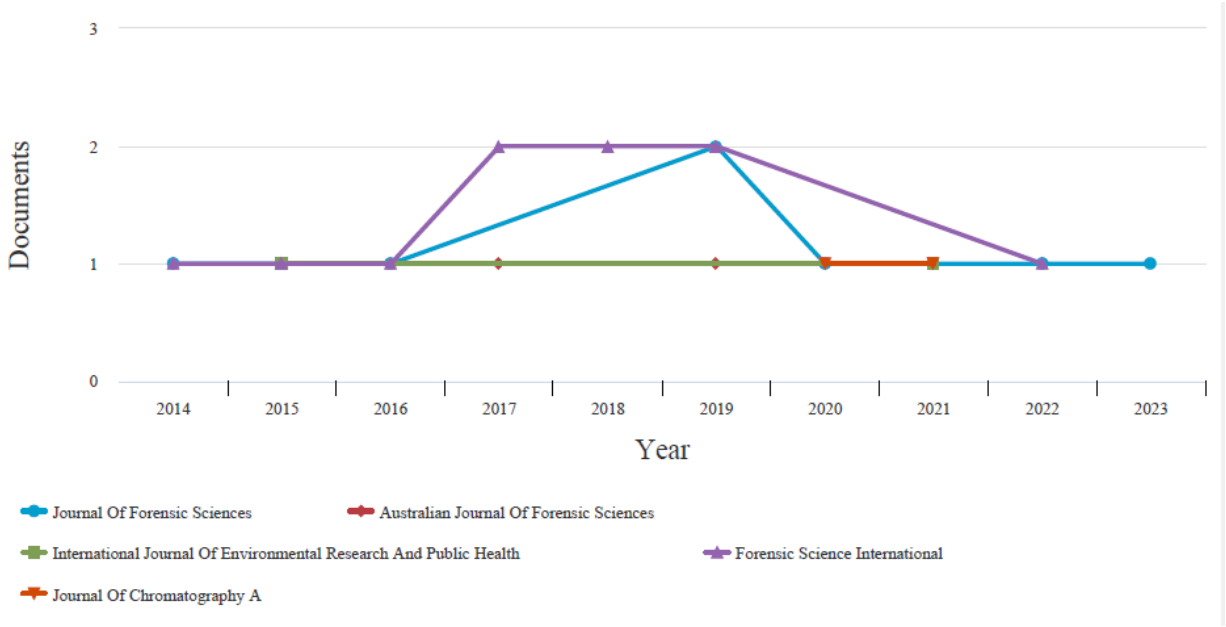

Figure 8. Top 5 Source Title/publisher in Environmental Forensic

Contribution of Authors to Environmental Forensic

Based on an analysis of articles related to environmental forensics published from 2014 to 2023, it is evident that there are notable variations among authors in terms of the number of documents they have published. Notably, Pringle, J.K. emerges as a highly influential and prolific author in environmental forensic research.

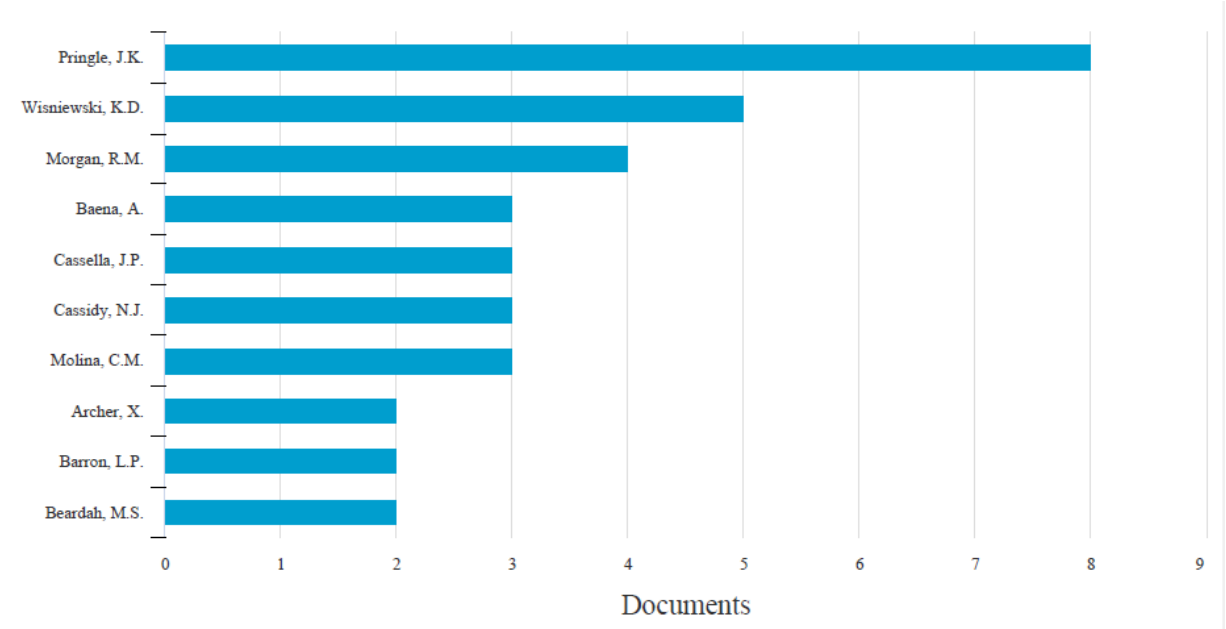

Figure 9. Top 10 Authors Publish on Environmental Forensic

Of the eight publications published by Pringle, J.K., the most remarkable one has received 33 citations, surpassing all other authors in this subject. Following Wisniewski, K.D., and Morgan, R.M., the pattern persisted, with both writers producing over three publications yearly. Notably, Wisniewski, K.D., who ranks second in publication count, has the fewest citations (8 citations) compared to Morgan, R.M. (36 citations). Nevertheless, he possesses more publications than Morgan, R.M. (refer to Figure 9).

The Most Frequently Utilised Keywords in Research

Within this section, we examine the material by scrutinising the dispersion of keywords. The presentation will include an interactive co-occurrence map showcasing the top 5 keywords in environmental forensic recovery publications. A keyword density visualisation map and a keyword timeline view will also be featured. Using co-occurrence keywords can accurately indicate the current areas of intense research focus within a specific subject, offering supplementary scientific investigation evidence (Gong et al., 2021). This method is frequently employed to assess the significance of publications by analysing the connections between citations or the associations between words inside the publications (Eck & Waltman, 2014). Six hundred twenty-eight keywords were extracted from the 13 publications, with a minimum occurrence threshold of 5. For each of the 13 keywords, the total strength of the co-occurrence links with other keywords will be calculated. The keywords with the greatest total link strength will be selected. Number of keywords to be selected is 11. These keywords are specifically relevant to environmental forensics as a recovery approach. The co-occurrence network of keywords in forensic sciences was produced using the VOSviewer software, as shown in Figure 9; this was achieved through data analysis. Table 3 presents the occurrences and total link strength of selected keywords.

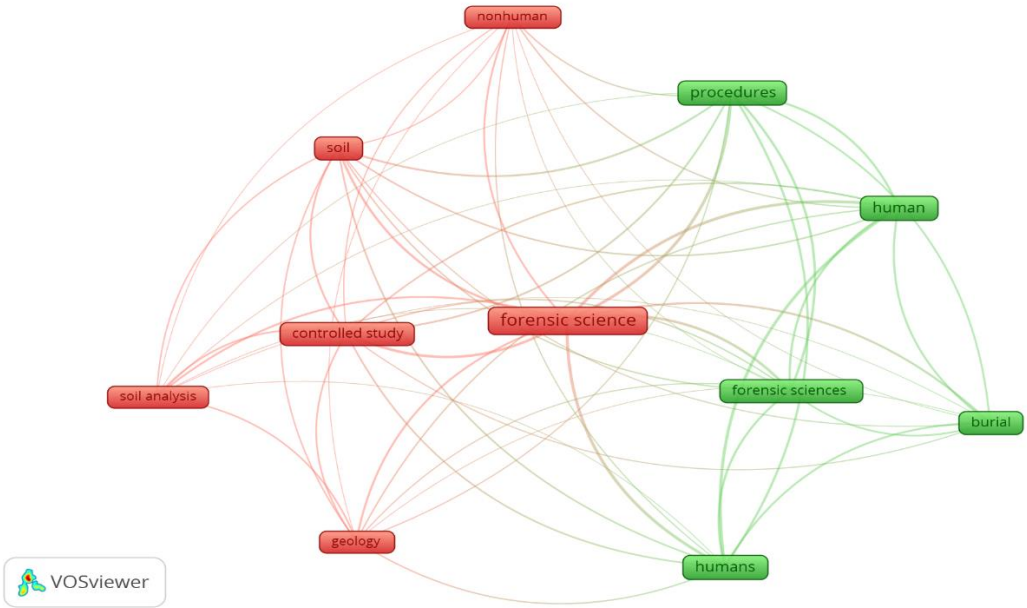

Figure 10. Network Visualization of Keywords

Table 3. Occurrences and total link strength of keywords

No	Keyword	Citations	Total link strength
1	Forensic science	33	123
2	Human	13	74
3	Humans	12	71
4	Prosedures	12	71
5	Controlled study	11	60
6	Forensic sciences	10	57
7	Soil	8	53
8	Burial	7	43
9	Geology	6	37
10	Soil analysis	6	30
11	Nonhuman	5	28

The weights of the nodes are indicated by the dimensions of the nodes and the text within the image. The weight is directly proportional to the knot's size and the word (Zhang et al., 2021). The strength of a relationship between two nodes is directly proportional to their proximity, with interactions with shorter distances being more likely to be stronger. The line connecting the two keywords signifies their initial co-occurrence. According to Hernández-Torrano and Ibrayeva (2020), the probability of a line appearing in a group increases as its thickness increases. A cluster consists of nodes that share the same colour. VOSviewer divides the published keywords relevant to environmental forensic into two distinct groupings (Hernández-torrano & Ibrayeva, 2020).

"Forensic science" was the most commonly utilised, appearing 33 times. The terms that were most commonly mentioned were "human" (13 occurrences), humans (12 occurrences), procedures (12 occurrences), controlled study (11 occurrences), forensic sciences (10 occurrences), soil (8 occurrences), burial (7 occurrences), geology and soil analysis (6 occurrences), and nonhuman (5 occurrences), among others (refer to Table 3). The study focuses on three fundamental keywords that describe the topic. Moreover, environmental forensic research frequently focuses on recovery and performance. The strength of the link between two nodes represents the frequency of co-occurrence between them.

A quantitative indicator can be utilised to describe the relationship between two nodes (Pinto et al., 2014). The overall link strength of an individual node can be determined by adding together the link strengths of that node and all other nodes. Figure 9 displays a node labelled "forensic science" outlined with a bolder line. This node encompasses the terms "human" (13 occurrences), "humans" (12 occurrences), and "procedures" (12 occurrences). The robust correlation between "forensic science," "human/humans," and "procedures" suggests that forensic science is not only vital for people but also intimately linked to procedural aspects, indicating a close integration of forensic science with performance.

Keywords in Research Trends

VOSViewer examines the keywords that appear most frequently in publications throughout a specific year. The analysis reveals the fluctuation of keyword trends from 2014 to 2023. The node's color represents the mean annual publication count associated with the node (Eck & Waltman, 2014). Blueness nodes are keywords primarily used at the start of a research period. Simultaneously, an increased number of yellow nodes correlate to keywords that have been recently mentioned. By classifying the most commonly utilised terms, one can ascertain the prevalence of specific discussion themes and identify those less frequently mentioned.

Figure 11 reveals several emerging research areas in environmental forensic, identified through the analysis of high-frequency keywords from recent publications (2017-2021). These areas include disappearance, period, training, surface geophysics, mass gravity, attempt, individual, knowledge, part, person, face importance, and gap. From the given issues, it can be inferred that there is a lack of shared understanding of forensic science. This lack of knowledge is now influenced by factors such as gaps, time periods, and training, which in turn impact the efforts and effectiveness of conducting research on environmental forensics.

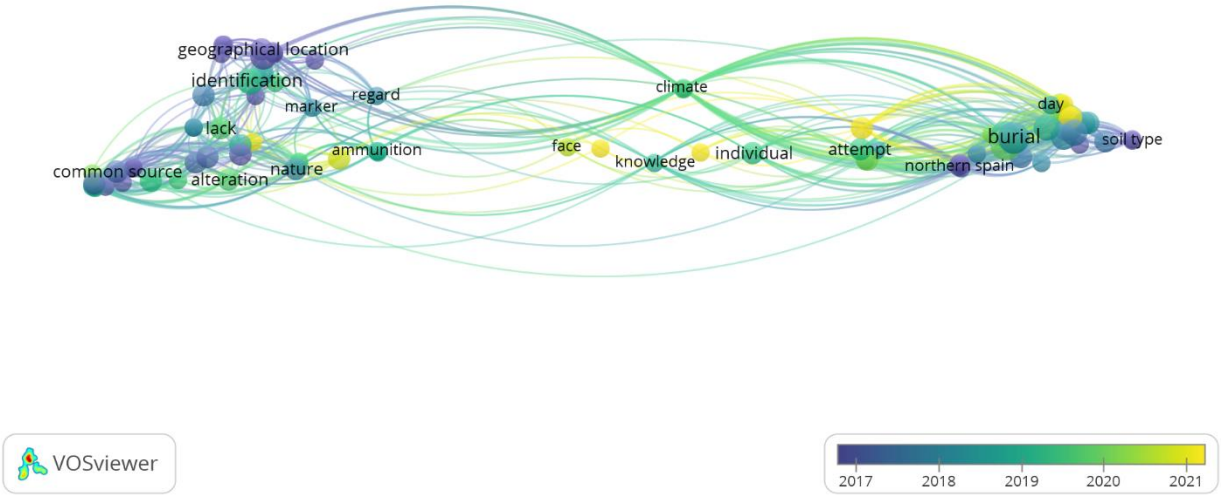

Figure 11. Keyword Trends

Conclusion

An investigation of bibliometric data on environmental forensic research identified global research patterns. This study utilised keywords to identify the most pertinent papers from the Scopus database. A total of 13,243 documents were acquired about this conversation topic. After refining the search to include articles published from 2014 to 2023, 10,117 papers were discovered. Based on the findings, the United Kingdom, Australia, Colombia, France, and the United States are the most productive countries in this research, exhibiting the most significant volume of published papers globally. Many publishers publish articles on the "Forensic Science International," publishing the most in this field. According to an analysis of all the widely cited papers, 25 authors have published at least two papers in this field. In addition, four authors have published more than three documents, namely pringle, jamie k. (7 documents and 141 citations with a total link strength of 8), wisniewski, kristopher d. (4 documents and 74 citations with a total link strength of 7), cassidy, nigel j. (3 documents and 70 citations with a total link strength of 5), baena, alejandra (3 documents and 19 citations with a total link strength of 2) are considered influential authors in this field.

In addition, the author's study of keywords uncovers two clusters, suggesting the presence of two interconnected groupings of terms. The keywords used to represent each cluster were "controlled study," "forensic science," "geology," "nonhuman," "soil," "soil analysis," "burial," "forensic sciences," "human," "humans," and "procedures." In the present year of publishing, numerous novel and burgeoning keywords are evident, signifying that these subjects are recent additions to the field of environmental forensic. Finally, the study will conclude by synthesizing the overarching trends and contributions, highlighting the implications for future research directions, policy considerations, and the continued development of Environmental Forensic Research. Through this comprehensive approach, this research endeavors to significantly contribute to the understanding and advancement of Environmental Forensic studies, providing valuable insights for scholars, practitioners, and policymakers alike. The results of this study have implications for the worldwide environmental forensic research field. They can serve as a roadmap for future investigations in the most pertinent domains and research topics.

Limitations and Recommendations

Our study has multiple constraints. The Scopus database is the exclusive repository of literature pertinent to our inquiry. While Scopus is quite comprehensive, certain studies within this topic may be indexed in alternative databases or not indexed at all. Therefore, an additional database is necessary to complement and enhance the existing study literature. Furthermore, the VOSViewer analysis considers the author's requirements while establishing the threshold, but it merely arranges the data without truly capturing the writer's requirements. Furthermore, data cleansing depends entirely on the program and expects everything to function well.

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