A REVIEW CONTRIBUTION TO ENVIRONMENTAL CRIME: CURRENT STATUS, DEVELOPMENT, AND FUTURE RESEARCH DIRECTIONS
Uma revisão contribuição para o crime ambiental: estado atual, desenvolvimento e direções de pesquisa futura

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ABSTRACT

In this study, the researchers find the key spots and recent changes in environmental crime. Using bibliometric analysis, the researchers examined a sample of 772 research from the ISI Web of Science database to find research activity on environmental crime between 2004 and 2022. Also, the researchers visualized the knowledge domains in this field using bibliometric software like CiteSpace and R-Biblioshiny. The research unravels the most influential published articles and authors on their citations and publications and their location and significance within the connection. The researchers further examined the recent themes, identified the barriers to developing literature in this field, and made recommendations for future research. Research on environmental crime globally lacks cross-border collaborations between emerging and developed economies. The researchers concluded the study by recommending three future research directions.
Keywords: environmental crime, environmental law, environmental violations, bibliometrics

UMA REVISÃO CONTRIBUIÇÃO PARA O CRIME AMBIENTAL: ESTADO ATUAL, DESENVOLVIMENTO E DIREÇÕES DE PESQUISA FUTURA

A review contribution to environmental crime: current status, development, and future research directions

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RESUMO

Neste estudo, os pesquisadores identificaram os pontos-chave e as mudanças recentes no crime ambiental. Utilizando análise bibliométrica, os pesquisadores examinaram uma amostra de 772 pesquisas do banco de dados da ISI Web of Science para encontrar a atividade de pesquisa sobre crime ambiental entre 2004 e 2022. Além disso, os pesquisadores visualizaram os domínios de conhecimento nesse campo usando softwares bibliométricos como CiteSpace e R-Biblioshiny. A pesquisa revela os artigos e autores publicados mais influentes em suas citações e publicações, assim como sua localização e importância dentro das conexões estabelecidas. Os pesquisadores também examinaram os temas recentes, identificaram as barreiras para o desenvolvimento da literatura nesse campo e fizeram recomendações para futuras pesquisas. A pesquisa sobre crime ambiental globalmente carece de colaborações transfronteiriças entre economias emergentes e desenvolvidas. Os pesquisadores concluíram o estudo recomendando três direções para futuras pesquisas.
Palavras-chave: crime ambiental, direito ambiental, violações ambientais, bibliometria

INTRODUCTION

In our present societies, environmental crime has become an inevitable menace that has posed a greater risk to the environment and, thus, human and animal life because of the misuse of the abundant natural resources available. Environmental crime has been explained as any activity that has an immediate and direct impact that destroys the environment's natural resources (Dura & Belishta, 2013; Thornberry, 2012). Environmental crimes are also those activities that emerge from violating enacted rules set to regulate environmental calamities (Mistura, 2018; Romoke Monsurat et al., 2019). Environmental crimes can be realized in many areas. The area of biodiversity comprises illicit trade of species that have been threatened, like wild flora and fauna. Thus, the controls are circumvented under the 1973 Convention on International Trade in Endangered Species (CITES) (Faroque & South, 2022; Rodríguez Goyes, 2021). Also, illicit whaling, which breaks the regulations enacted by the International Whaling Commission, and illicit usage of genetic resources constitute environmental crimes. Environmental crime is also seen in the area of waste. In this area, the illicit movement of poisonous substances breaks the regulation of the 1989 Basel Convention. Also, many industries globally cannot afford the standard means of disposing of their waste, resulting in the illegal disposal of waste (Solodov & Zebek, 2020). In this area, the dumping of waste oil at sea, violating the International Maritime Organisation's Marine Pollution (MARPOL) Convention, concerns many states with long shorelines (Chowdhury & Karim, 2022). Other environmental crimes are associated with banned substances. For instance, the illicit production and trade of ozone-depleting substances (ODS) breaches the regulations mandated by the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer.

Although environmental crime harms the environment at large, various stakeholders are taking all steps to improve pragmatic and operational environmental law enforcement measures to help combat the menace (Hubert, 2021; Khan & Chang, 2018). Researchers have explored and contributed to issues in environmental crime. Lambrechts (2016) contributed to this area with the title "Environmental Crime in Sub-Saharan Africa – A Review and Future Challenges." The researcher focused on the significance and importance of examining environmental crime issues, especially in southern Africa, while suggesting topics for future research in sub-Saharan Africa. For instance, future research on harmful waste discarding and African state power. Wright (2011) also contributed to the title, "Conceptualizing and combating transnational environmental crime." The researcher tries to rectify this by conceptualizing transnational environmental crime and suggesting ways forward for countermeasure development.

To a considerable extent, this research investigated the problem of environmental crime, and its impacts, concluding that the harmful nature of international environmental crime necessitates a greater focus on its monitoring. Routhe and Yeager (2005) also contributed to the title "Environmental Crime." Through a review approach, the researchers concluded that most states give supervisory agencies primary responsibility for responding to environmental illegalities and crime. They generally do not operate vigorously, and the penalties are not severe. The present paper aims to describe the extent, nature, and several responses to environmental crime while exploring future developments. This review study varies from those of other authors in many ways. To the best of the researchers understanding and knowledge, no research in this field has adopted and combined the bibliometric approach and content analysis to gather and integrate existing proof of an environmental crime and possible ways to curb the menace. Second, earlier review studies used a more limited data period or did not state the specified period than our study. Third, this research identifies the issues impeding investigation on environmental crime and offers directions for future research. The research aims to explore environmental crime from these perspectives;

(a) To conduct an evidence-based content analysis of current literature on environmental violation and its management.
(b) To reflect on the strategy and policy implications and explore future research opportunities.

Using the bibliometric analysis, the researchers find the publication patterns and intellectual construct in environmental crime. Based on this, the study further addresses the following Research Questions (RQs): RQ1: What is the present publication trend in environmental crime? RQ2: Which are the most influential articles on environmental crime? RQ3: Which themes concerning environmental crime are the most popular among scholars? RQ4: Who are the most influential authors on environmental crime? RQ5: What is the current state of collaboration involving

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environmental crime? RQ6: What is the intellectual construct of present research on environmental crime? RQ7: What forms of issues hinder research on environmental crime? RQ8: What areas involving environmental crime need further study?

1 OVERVIEW OF ENVIRONMENTAL CRIME

Studies on environmental crime and other related environmental issues have shown that since the beginning of the 21st century, more environmental protection awareness has been created especially through academic writings and debates. These are intended to reduce the rate of environmental crimes globally (Purvis et al., 2019; Spash & Aslaksen, 2015). This environmental awareness to reduce environmental crimes is gradually having an impact. Tienhaara (2018) adds that when stakeholders started implementing reasonable environmental regulations, environmental crimes warranted an inconsequential intensity of civil punishments or fines. These did not serve as a severe deterrent for people who committed environmental crimes. Jin et al. (2016) affirm that through awareness, and rigorous environmental crime management, various stakeholders understand the need to protect the environment.

The scope of environmental crime has generally been broadened. In the United Kingdom (UK, England), the Disraeli's Rivers Act of 1876 (Prevention of Pollution Act) was dominant as a legislative measure regulating environmental crime (Hough, 2019). In the United States (US), the Refuse Act of (1899) served as the first national regulation intended to control pollution as a form of environmental crime (Russo, 2017). Also, the US Clean Air Act (1963), the Resource Conservation and Recovery Act (1976), the Clean Water Act (1972), and other landmarks of federal regulation provided criminal punishments for an extensive list of environmentally destructive actions (Adipah & Kwame, 2019; Autor et al., 2019; Orford, 2021). Lyon and Maxwell (2017) add that there is an increasing number of countries that have also provided illicit punishments for breaching environmental laws. Mistura (2018) also affirms that globally, environmental regulatory agencies have redefined, created much awareness, and charged corresponding illegal punishments for a wide range and increased number of actions that harms the environment. Researchers (Ashour et al., 2015; Moroke et al., 2018; Faroque & South, 2022) add that monitoring the development and multi-faceted environmental offense challenge by various countries necessitates a stable, cohesive, and comprehensive method. Stakeholders across the globe also need to reconsider traditional management and growth and create a strong corporation between public and private sector actors (Burivalova et al., 2017; Domínguez & Luoma, 2020; Pires & Moreto, 2011).

Environmental crimes generally include illicit activities that pose a greater threat to the environment - water, air, earth and soil, flora and fauna (Mistura, 2018; Routhe & Yeager, 2005). Over time, these illicit actions might worsen, creating more problems, especially concerning climate change. Environmental crimes may either be local (Cochran et al., 2018), for example, poaching, or maybe transnational (Gibbs et al., 2015), for example, trading in wildlife, smuggling in electronic waste and timber, among others). Several factors weaken the framework of environmental crimes - social, economic, and political. These are realized in the form of lower incomes generated from businesses or, to a larger extent, loss of tax revenue whichhas an adverse impact on societies (Solodov & Zebek, 2020). Although several literatures contribute to discussions on environmental crime, they are primarily discrete.

2 METHODOLOGY

2.1 Data sources

The bibliometric analysis considers scientific and statistical methods to explore the types, features, and forms of document structure by taking documents as the research object. The data for this study was gathered from the Core Collection of Web of Science (WoS) collected by Thompson Reuters and jointly integrated into the ISI Web of Knowledge. WoS is a generally adopted catalog that gives statistics on document types, languages, countries, institutions and authors, funding agencies, journals, and subject categories. WoS allows researchers to download all records and cited references of articles published in .txt format, which can be used to generate maps and for further

analysis in other software. For this review article, academic publications on environmental crime from 2004 to 2022 were downloaded from the WoS database on 20th December 2022.

The search terms for this review article were TOPIC: ("Environmental crime" OR "nature of environmental crime" OR "Environmental crime management" AND "combating environmental crime" AND "legal framework" OR "environmental laws") set to a timespan of 2004 - 2022. The search generated 995 documents, further reduced via screening based on document type and language. Consequently, the final document used for further analysis was 772.

2.2 Analyzing Data using CiteSpace Software

CiteSpace is among the commonly used tools for imagery and visualization in scientific research (Chen, 2006a, Chen et al., 2010). The CiteSpace software is an open-source Java application that cites and classifies information on related literature and continues to produce a graphic representation of the data generated (Chen, Dubin & Kim, 2014a). Two components make up CiteSpace's visualization and mappings: nodes and links. The nodes represent authors, institutions, countries, journals, keywords, subject groupings, and cited references. At the same time, links replicate the co-occurrence or co-citation association between nodes (Chen et al., 2014b). The physical characteristics of the nodes are such that they usually define the evolution and growth of a research domain.

Figure 1 illustrates the general characteristics of publications on environmental crime from 2004 to 2022. Furthermore, a collaboration analysis was conducted to plot the cooperation links of institutions and countries in this area. To better understand the academic structure of the research area, the researchers continued to determine the co-citation of the documents, journals, and subject categories. CiteSpace was then used to track climate change laws research by identifying the research area and analyzing significant keywords regarding the origin, development, and current status. Zhang et al. (2020) suggest that CiteSpace parameters, such as time slice, node type, and pruning, must be thoroughly checked and selected conclusively with the study's objectives. In this regard, the researchers set the study parameters to (a) time slicing = 2004 – 2022; (b) years per slice=1; (c) node type= institution, country, keyword, cited journal, subject category (d) network selection criteria was based on top N=50; (e) link strength and scope= cosine and within slices, respectively; (f) pruning= pathfinder and sliced network.

Figure 1: The flow of the research
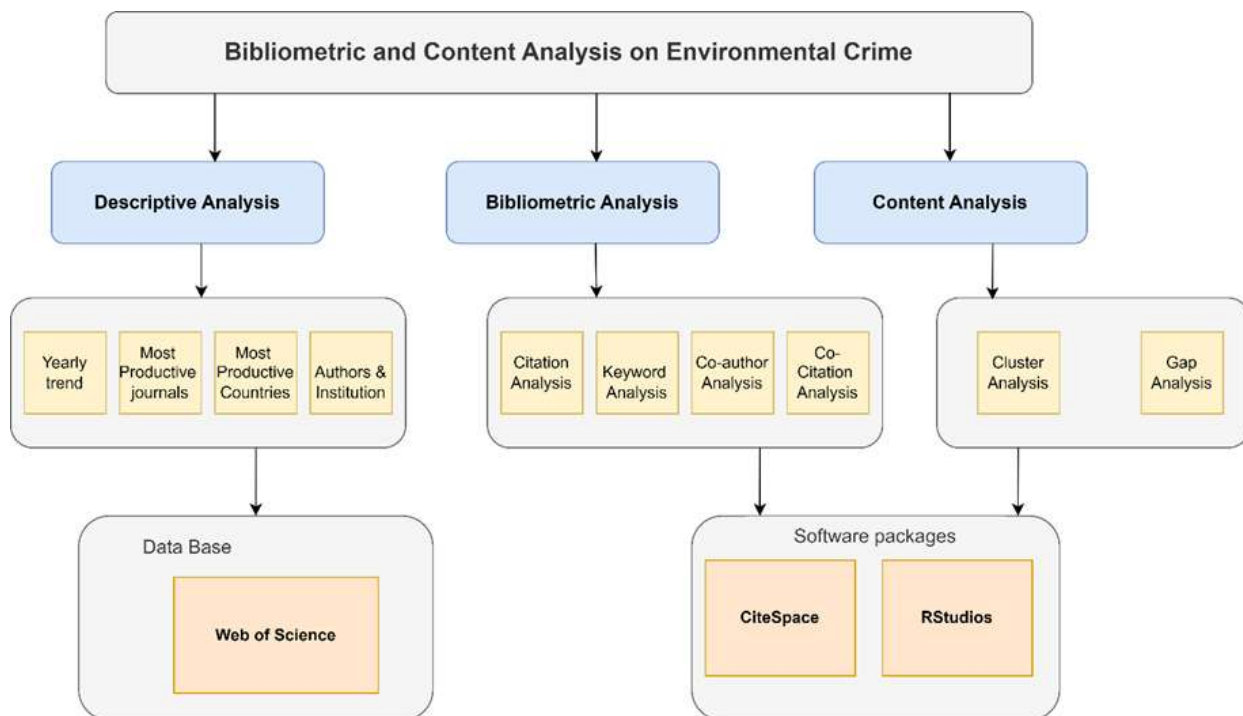
2.3 Measure of influence: H-index and impact factor

To best measure the cumulative impact and significance of an individual's scientific output with the advantage of being unbiased, the researchers adopted the h-index as proposed by Hirsch in 2005 (Hirsch, 2005). In this vein, one is associated with a particular article published and may be an author, institution, country, or journal. Brandão and Soares de Mello (2019) add that the h-index links to a particular period in the *h* papers from an individual have been cited at least *h* times. Hence, the researchers utilized this index with the normal surveys of the total number of citations and publications. Impact Factor (*IF*) is also another significant performance indicator that is widely used for journals to assess the quality of journals. The *IF* represents the source's mean citations of journal articles published metric over two years (Ma et al., 2018). The researchers, therefore, obtained the *IF* of top-performing journals from the Citation Reports (JCR) 2021 edition.

3 RESULTS AND DISCUSSIONS

The researchers answered RQ1, (What is the present publication trend in environmental crime?) by examining the trends in publication years, countries, productive journals, and the leading authors and institutions. The researchers utilized the data gathered from the ISI WoS Core Collection database.

3.1 Publication by year

Figure 2 displays the trend in publications and citations from the WoS Core Collection from 2004 to 2022. Generally, between 2004 to 2022, there were several publications, although there were fluctuations in the number of publications. It could be realized that between 2005 and 2017, there were some fluctuations in the publication number. The graph further illustrates the number of citations documented for publications each year. The number of citations between 2004 to 2022 steadily increased throughout the period. The year 2020 recorded the highest citation. Overall, the total number of documents obtained from the WoS, which was 995 and filtered to 772, has been cited 12,040 times. The low levels of publications from 2004 to 2016 are associated with the lack of data, knowledge, and awareness (Nellemann et al., 2016). However, as awareness and several countermeasures keep rising to curb environmental crime, 2017 to 2022 saw increased publications (UNEP, 2018).

Figure 2: Annual distribution of publications and citations
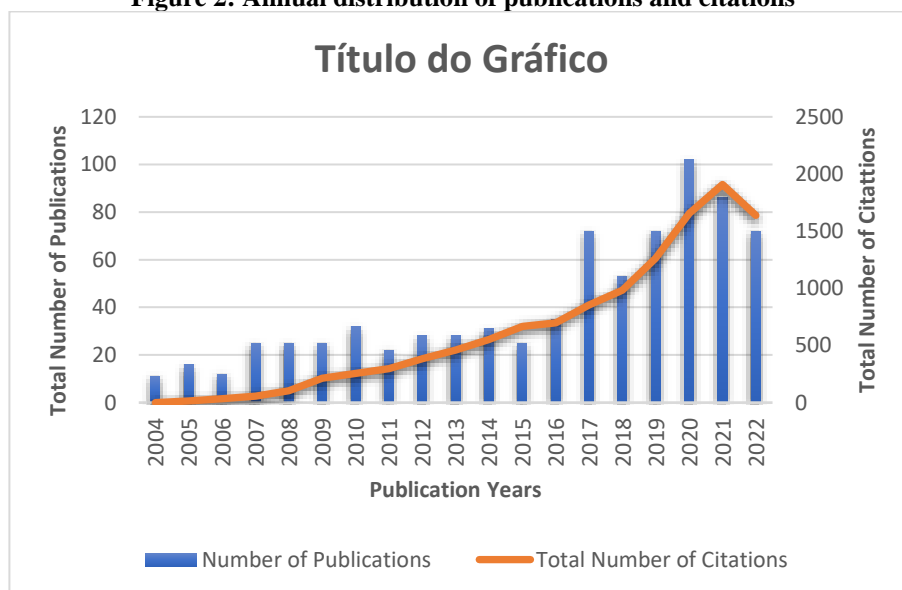
3.2 Publishing activity by country

Research on environmental crime has gained much attention from a global perspective and has attracted contributions from 86 countries. Table 1 displays the top 20 publishing countries on environmental crime, with the top being the United States of America (235, 30.440%), the People's Republic of China (80, 10.363%), and Brazil (73, 9.456%). The top 5 countries from which the authors contributed represent the various continents, suggesting that environmental crime is a global crisis (Anne-Michelle, 2015; Cochran et al., 2018).

Table 1: Number of articles published in Countries

Countries	Number of articles published	% of 772
USA	235	30.440%
PEOPLES R CHINA	80	10.363%
BRAZIL	73	9.456%
ENGLAND	60	7.772%
AUSTRALIA	54	6.995%
GERMANY	36	4.663%
ITALY	31	4.016%
SPAIN	30	3.886%
INDIA	29	3.756%
CANADA	24	3.109%
NETHERLANDS	24	3.109%
FRANCE	19	2.461%
PAKISTAN	17	2.202%
BELGIUM	16	2.073%
NIGERIA	15	1.943%
SOUTH AFRICA	14	1.813%
IRAN	13	1.684%
MEXICO	12	1.554%
PORTUGAL	12	1.554%
NORWAY	10	1.295%

Figure 3 displays the collaboration network of countries with 15 ≥ publications based on corresponding author addresses. The network comprised 83 nodes with 213 links, with a density of 0.0626, signifying a relatively close link among the countries. Evidently, the countries with the most published articles have a relatively closer connection. US, UK, Australia and China were essential nodes linking various groups to large nodes because they recorded higher centralities of 0.40, 0.28, 0.13, and 0.13, respectively.

Figure 3: Collaboration network of countries
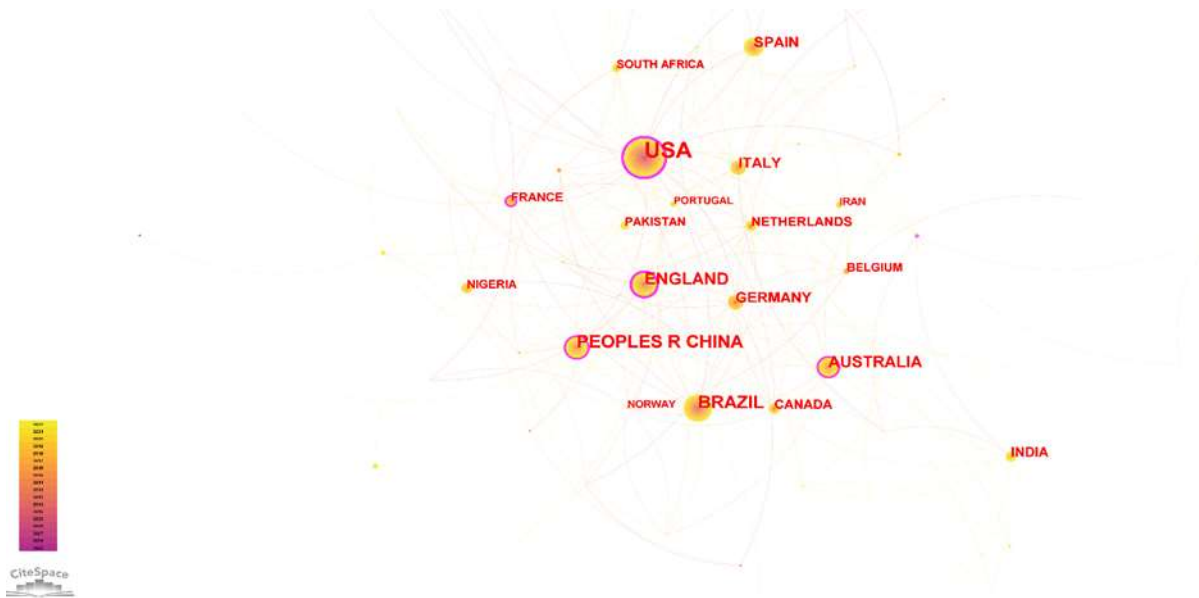
3.3 Most Productive Journal

The 995 articles later filtered to 772 were associated with 482 journals. Table 2 represents the top 20 most productive journals on environmental crime. The leading journals are Crime Law and Social Change, followed by Sustainability, Journal of Cleaner Production, Environmental Science and Pollution Research, and Journal of Environmental Law. These most productive journals were associated with subject categories like Environmental Sciences, Environmental Studies, Law, Criminology Penology, and Green Sustainable Science Technology. Based on the IF associated with the various journals, it can be realized that the issue of environmental crime is gradually gaining much attention.

Table 2: Performance of the top 20 most productive journals

Journal	No.	% of 772	h-index	TC	IF
CRIME LAW AND SOCIAL CHANGE	20	2.591%	9	251	1.612
SUSTAINABILITY	18	2.332%	7	227	3.889
JOURNAL OF CLEANER PRODUCTION	16	2.073%	13	683	11.072
ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	12	1.554%	5	117	5.190
JOURNAL OF ENVIRONMENTAL LAW	10	1.295%	5	81	1.750
CRITICAL CRIMINOLOGY	8	1.036%	6	128	2.109
ECOLOGY LAW QUARTERLY	8	1.036%	3	38	-
HARVARD ENVIRONMENTAL LAW REVIEW	8	1.036%	4	44	-
MARINE POLICY	8	1.036%	5	58	4.315
SOCIETY NATURAL RESOURCES	7	0.907%	4	148	3.024
PLOS ONE	6	0.777%	4	106	-
ECOLOGICAL ECONOMICS	5	0.648%	5	191	6.536
ENVIRONMENTAL MANAGEMENT	5	0.648%	3	90	3.644

ENVIRONMENTAL MONITORING AND ASSESSMENT	5	0.648%	4	71	3.307
EUROPEAN JOURNAL OF CRIMINOLOGY	5	0.648%	4	50	1.725
JOURNAL OF ENVIRONMENTAL MANAGEMENT	5	0.648%	4	166	8.91
CONSERVATION BIOLOGY	4	0.518%	3	56	-
ECOLOGY AND SOCIETY	4	0.518%	3	134	4.403
ENERGY POLICY	4	0.518%	2	424	7.576
ENVIRONMENTAL EARTH SCIENCES	4	0.518%	3	29	3.119

Note: No. = Number of articles published; TC= total Citations; IF=impact Factor

3.4 Publishing activity by author and institutions

Based on the documents retrieved from the WoS database, 2140 from 418 institutions have published articles on environmental crime. Table 3 displays the top 10 contributing authors and institutions. Lynch MJ has published 11 articles on environmental crime, followed by Stretesky PB, who published l0 articles, and White R has also published nine (9) articles. The University of California System was the most productive institution, which published 22 articles. The State University System of Florida published 21 articles, and the Universidade de Sao Paulo published 13 articles. While most of these authors and institutions contributing to environmental crime issues are in the US, most study results are useful globally.

Table 3: Top 10 publishing authors and institutions on environmental crime

| Author	TP	TC	Institutions	TP	% of 772
Lynch MJ	11	183	UNIVERSITY OF CALIFORNIA SYSTEM	22	2.850%
Stretesky PB	10	192	STATE UNIVERSITY SYSTEM OF FLORIDA	21	2.720%
White R	9	114	UNIVERSIDADE DE SAO PAULO	13	1.684%
Gibbs C	6	219	UNIVERSITY OF SOUTH FLORIDA	12	1.554%
South N	6	126	UNIVERSITY OF TASMANIA	12	1.554%
Brisman A	5	48	TEXAS A M UNIVERSITY SYSTEM	10	1.295%
Long MA	5	65	UNIVERSITY OF NORTH CAROLINA	10	1.295%
Martin AM	5	131	UNIVERSITY OF WASHINGTON	10	1.295%
Rousseau S	5	38	UNIVERSITY OF WASHINGTON SEATTLE	10	1.295%
ıi AR	4	69	COLORADO STATE UNIVERSITY		.166%

Note: TP=Total Publication; TC=Total Citation

3.5 Citation network analysis

The second RQ (Which are the most influential articles on environmental crime?) sought to find the most influential articles. To find answers to this question, the researchers analyzed the citation networks of the articles published. Trujillo and Long (2018) believe that several approaches can help authors to measure the impact of a research publication, but adopting citation analysis is much more appropriate since it shows the intellectual linkages that exist. The authors utilized CiteSpace to conduct the citation analysis. Table 4 shows the top 10 most cited articles from the documents gathered from the WoS database. Ganeriwal et al. (2008) contributed to this field with an article titled "*Reputation-based framework for high integrity sensor networks*" with 408 total citations. Figure 4 gives a pictorial representation of the leading node citations in the network with a high number of total citations. The total citation assesses an article's dominance in a particular literature field. Articles that have the highest total citation have a greater impact on issues in the field of environmental crime.

Table 4: Top 10 most cited articles

| Articles	Journal	Total Citation	References
Reputation-based framework for high integrity sensor networks	ACM Transactions on Sensor Networks	408	Ganeriwal et al., 2008
Economic impacts from the promotion of renewable energy technologies: The German experience	Ruhr Economic Papers	330	Christoph et al., 2009
The reputational penalties for environmental violations: Empirical evidence	The Journal of Law and Economics	273	Karpoff et al., 2002
Strongly interacting species. conservation policy, management, and ethics	BioScience	219	Soule et al., 2010
How much is enough? The recurrent problem of setting measurable objectives in conservation	BioScience	203	Tear et al., 2005
Competitive strategy in remanufacturing and the impact of take-back laws	Journal of Operational Management	200	Webster & Mitra, 2007
Why do firms engage in environmental management? An empirical study in China	Journal of Cleaner Production	188	Zhang et al., 2008
Environmental impacts of absorption-based CO2 capture unit for post-combustion treatment of flue gas from coal-fired power plant	International Journal of Greenhouse Gas Control	160	Thitakamol et al., 2012
Implementation of Chinese environmental law: Regular enforcement and political campaigns	El Taller De La Historia	140	Rooij, 2006
Towards Interdisciplinary Scholarship on Environmental Crimes and Risks	Towards Interdisciplinary Scholarship on Environmental Crimes and Risks	138	Gibbs et al., 2009

Figure 4: Leading node citations in the network
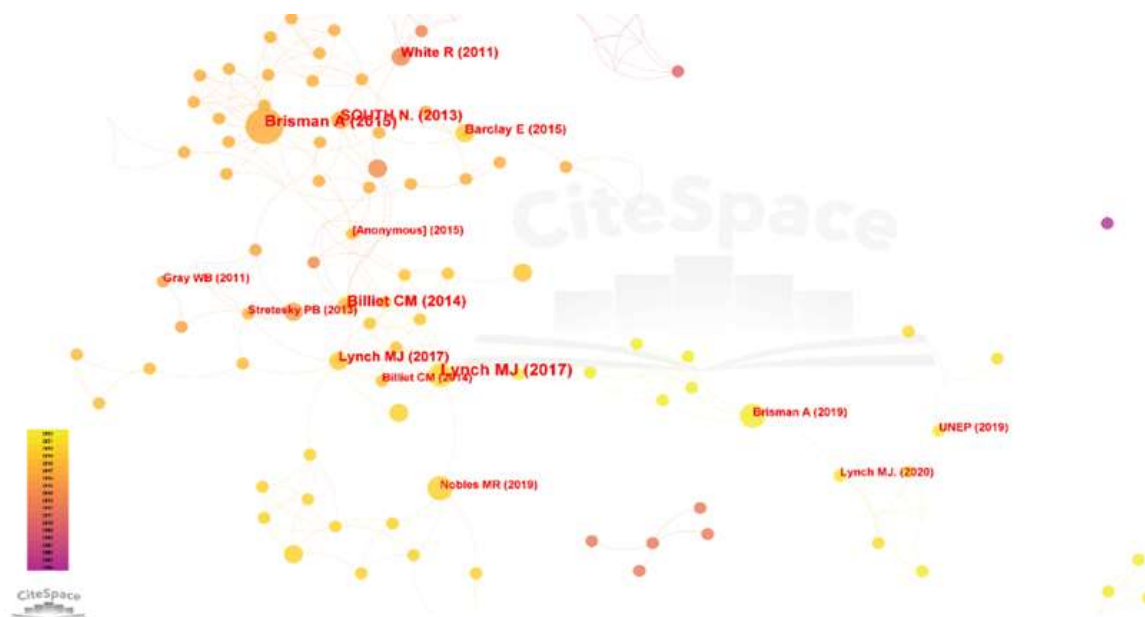
Researchers conduct keyword co-occurrence analysis to show how adequately the author's keywords characterize the literature of article content (Bilska & Tomaszewska, 2020; Zhang et al., 2020). When two author keywords appear in an article, it is termed a keyword co-occurrence and signifies the relationship that binds the two ideas (Aboagye, Effah, et al., 2023; Aboagye, Zeng, et al., 2023; Agyepong & Liang, 2022; Effah et al., 2022; Mao et al., 2015). For the researchers to answer RQ3 (RQ3: Which themes concerning environmental crime are the most popular among scholars?), attention was focused on categorizing the prevalent articles that appeared in the various contributions of documents gathered on environmental crime. The CiteSpace software was utilized to address the RQ3.

To understand the various strategies put in place for environmental crime, researchers mainly adopt the co-occurrence analysis (Wei, 2020), which helps them determine the performance and information flows (Khasseh et al., 2017). Figure 5 displays the frequently occurring author keywords. For the author's keyword analysis, *environmental crime, environmental law*, *policy, conservation, environmental regulation, and performance have gained much prominence*. The researchers again used the CiteSpace software to calculate the degree of centrality of the author keywords. The degree of centrality is the number of ties a node has (Zhang & Luo, 2017). The degree of centrality within the author keywords network helps to determine the comparative significance within the network concerning their ties (Tang et al., 2021). Based on the calculations, author keywords like *impact* had a centrality of 0.26, followed by *performance* (0.22), *management* (0.20), *environmental crime* and *enforcement* with 0.18. These centrality scores indicate a fair connection between the nodes of the author keywords compared to other author keywords in the network.

Figure 5: Co-occurrence connection of keywords
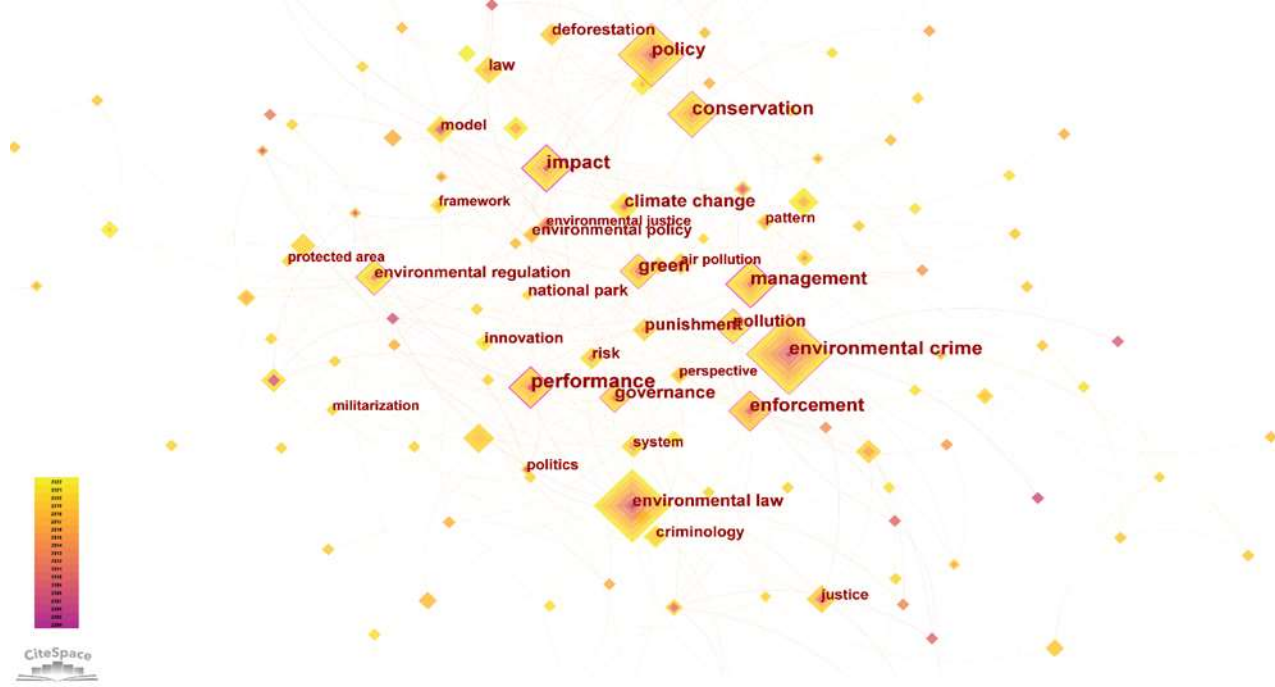
3.6 Co-authorship analysis

The researchers sought to answer RQ4 and RQ5 (Who are the most influential authors on environmental crime, and the current state of collaboration involving environmental crime?). As such, the researchers analyzed the current status of research collaboration amongst the authors and determined the most influential authors in environmental crime. When authors collaborate, it demonstrates a high level of intellectual association in scientific research (Kilicoglu & Mehmetcik, 2021). Co-authorship analysis helps reduce the margin of error and the multiple mistakes that authors are likely to make in their contributions, improving the quality of their published articles (Kraus et al., 2020). In this section, the researchers analyzed the extent of collaboration among authors and found the most influential authors within the collaboration network among authors. Figure 6 displays the leading authors in terms of collaboration, and they were Lynch MJ, Long MA, Billiet C and Rousseau S from the US, and the latter is Dutch. The network indicates that the research focuses on a few authors and largely the nodes for a network of two or three. Consequently, the networks are mostly made up of collaborations from the author's own country.

Figure 6: Author Collaboration
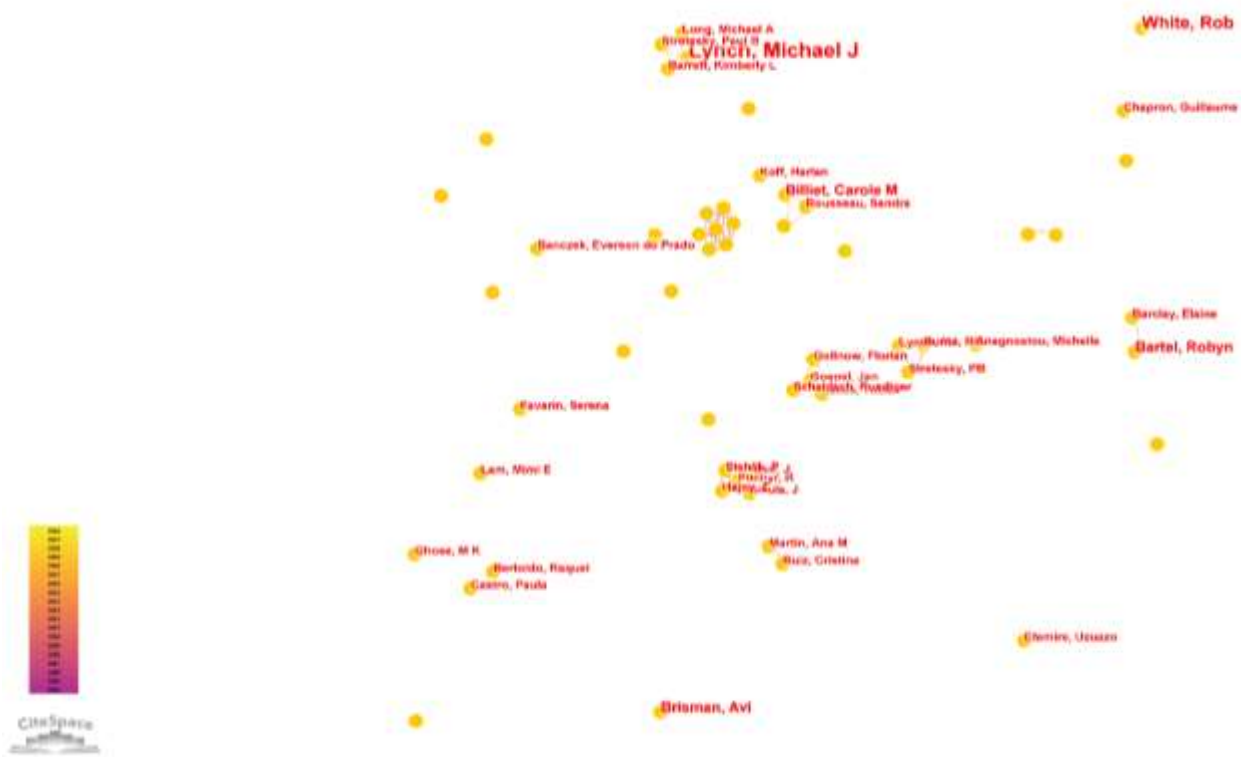
3.7 Co-citation analysis

Co-citation analysis refers to the number of times two articles are cited in the same paper cites two journals. In bibliometric analysis, co-citation analysis can uncover a field's intellectual construct (Afrane et al., 2022). The co-citation assisted tbe researcbers in showing the structure, directions, and advances in the research field of environmental crime. The researchers find answers to the RQ6 (What is the intellectual construct of present research on environmental crime?), which aims to understand the intellectual construct of the research on environmental crime utilizing co-citation and content analysis. Two articles are characterized by linked nodes when they co-occur in any research article. The researchers regard two publications as related and cited because they are expected to have a related subject matter. The researchers initially identified that 83 of the 772 articles are co-cited by other articles within the network.

3.8 Content analysis

The research clusters consist of 83 studies; hence, this section conducts a content analysis of the various clusters emphasizing the first 5 clusters. The clusters helped the researchers to find a common theme within the cluster for the analysis. This research used the top 10 articles in each cluster for this analysis, usually done in bibliometric analysis (Du et al., 2017; S. Gao et al., 2021). Using the CiteSpace software, the co-cited references of documents were grouped into different clusters grounded on a close relationship between the references (Chen et al., 2014). As displayed in Figure 7, the generated clusters are represented by a round curved structure with different colours that are closely interlinked.

The modularity value (Q), which indicates the extent of grouping with different limits centred on the co-citation network, was estimated as 0.7129. The researchers set the labeling source to "K," and the Log-Likelihood Ration (LLR) was adopted to conduct the clustering. LLR is a labelling algorithm that calculates and defines the main concept of each cluster. The silhouette score signifies the regularity of a cluster, and the stronger the value is to 1, the more

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reliable the cluster is (Chen et al., 2014b). Table 5 presents more evidence about the five biggest clusters created from the history summary by CiteSpace. It is evident that the clusters are very homogenous, and the clusters are consistent since the silhouette scores are, as presented in Table 5, close to 1.

Cluster #0 was the largest cluster generated, with 45 members of the co-cited references and a silhouette value of 0.786. The label for this cluster was an *environmental violation* by the LLR, and the mean cite year was 2013. This signifies that the cluster was formed from relatively recent documents through the period when the number of documents in this field began to rise sharply. The articles in this cluster generally reported on the various activities that constitute environmental crime or violations and also the corresponding punishments that follow (Billiet et al., 2018; Favarin & Aziani, 2020; Howes et al., 2017; Lynch et al., 2020; (Wortley & Townsley, 2016). The second largest cluster #1 had 41 members and was labeled *illegal sea turtle hunting*. The focus of environmental crime places much emphasis on animal poaching. When animal poachers are left to continually poach animals without going unpunished, these animals will go extinct (Billiet et al., 2018; Rizzolo et al., 2017). The third cluster #2, *environmental management,* had the second-highest silhouette score among the list in the table showing high reliability of co-cited references in this cluster. Articles published in this cluster hinge on the various strategies to help combat environmental crime (Howes et al., 2017; Niesten et al., 2017; Zhang et al., 2008).

The fourth cluster #3 labeled as air pollution, is one of the challenging environmental crimes. In this age of industrialization, several industries have emerged, so fighting this issue has become very difficult (Chiquetto et al., 2019; C. Gao et al., 2009; Thitakamol et al., 2007). The fifth cluster #4 is labelled *environmental law violation fine.* This cluster had the highest silhouette value of 0.947, which significantly suggests that the co-cited references in the cluster are closely linked. Articles in this cluster centred on some corresponding punishments that result from violating environmental laws enacted (Lynch et al., 2004; Martín et al., 2013; Nobles, 2019).

Figure 7: Cluster network of environmental crime research from 2004 to 2022 (different colours represent different clusters)
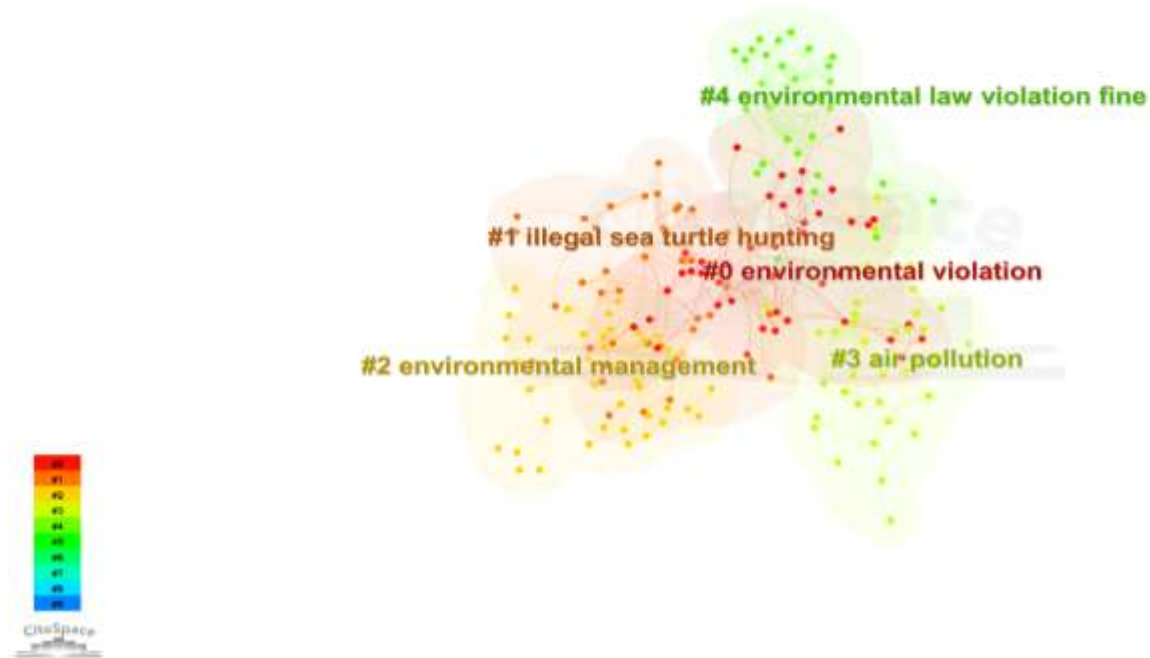
Table 5: Summary of the 5 largest clusters of co-cited references

Cluster ID	Size	Silhouette	Mean Year	Log likelihood ratio (LLR)
0	45	0.786	2013	environmental violation
1	41	0.808	2014	illegal sea turtle hunting
2	40	0.914	2010	environmental management
3	39	0.909	2014	air pollution
4	29	0.947	2011	environmental law violation fine

4 FINDINGS, LIMITATIONS, AND FUTURE AREAS OF RESEARCH

In this section, the researchers summarize their findings and answer RQ7 and RQ8 (What issues hinder research on environmental crime, and what areas involving environmental crime need further study?). The research gave a descriptive background to explain the current trend of research on environmental crime (RQ1). The research showed that more articles were published in 2020. This is driven by the growing transitional threat since environmental crime has become complex and has raised the priorities for law enforcement agencies and regulators. Most of the research on environmental crime focuses on US, China and Brazil, UK. These countries have very strong environmental policies to help sustain the environment.

The researchers also found that institutions and authors contributing to environmental crime are globally instituted. The citation analysis unraveled that more researchers are still needed in environmental crime (RQ2). The leading authors were Lynch MJ, who has published 11 articles on environmental crime; Stretesky PB, who published l0 articles and White R, also published 9 articles. However, researchers by Ganeriwal et al., 2008, Christoph et al., 2009 and Karpoff et al., 2002 have been cited the most in this field. Keywords and co-occurrence analysis suggested popular themes in environmental crime (RQ3). It was evident that *environmental crime, environmental law*, *policy, conservation, environmental regulation, and performance* are the keywords that dominate in this field. Much attention has been focused on environmental crime and its impact on environmental sustainability. This is plausible since environmental crime directly impacts the environment, so it needs urgent attention.

Concerning the most influential authors on environmental crime (RQ4 and RQ5), the co-authorship analysis was very useful. It was evident that there was relatively little collaboration among authors from a global perspective. Authors like Lynch MJ, Stretesky PB and Long MA have contributed significantly to the network. Although there are relatively few ties, these authors have significant group knowledge. The researchers suggest that collaborative efforts among authors should be encouraged. Making use of the co-citation analysis and content analysis, the researchers attempt to find the current intellectual construct of research on environmental crime (RQ6). The researchers find that this research consists of five main clusters. Cluster #0 aimed at environmental violations. Cluster #1 also focused on illegal sea turtle hunting which hinges on animal poaching and how they drive endangered species into extinction. Cluster #2 also focuses on environmental management. Articles in this cluster highlighted pragmatic measures to counter environmental crimes. Articles in cluster #3 addressed air pollution, which had become difficult to fight as industrialization increases. The fifth cluster #4 environmental law violation fine addresses some punishment for committing an environmental crime.

4. 1 Limitation to this research

Based on the findings and discussions, the researchers have identified these as limitations to the current research that hinder the growth of research in this field. This section also addresses the RQ7 (What forms of issues impede research on environmental crime?).

a). This field has a paucity of methodological theory development. Several empirical researches focus on environmental crime. There is a need for more conceptual articles that will provide a hypothetical approach to guide future research. Future research should look at this direction, which will develop a robust structure in this field.

b). There are insufficient data available in this field. Data availability does not allow researchers to contribute much in this field. A need, therefore, exists to develop a complete database to assist and encourage several researchers.

c). This bibliometric analysis review was conducted exclusively by concentrating on environmental crime. Hence, there is a chance for other scholars to make a comprehensive comparative study of specific issues on environmental crime. The subscription database where the data was retrieved started from the last decade (2004-2022), explaining why the authors' started the study in 2004. More so, the search phrases were used at the authors decision to reduce extreme contamination in the database as much as possible. Selection bias is possible since the study documents were based on the WoS Core Collection. Although the WoS is broad and reliable, more sources like Scopus and Google Scholar could present a more thorough concept and ideas. Nevertheless, if these limitations are solved, we do not expect a substantial difference from the findings of the current review.

4.2 Future research direction

The researchers additionally sought to answer RQ8 (What areas involving environmental crime need further study?). Thus, this section used RStudio to find possible areas for future research. Here are some research gaps that future researchers could address.

More conceptual studies are needed. As earlier suggested by the researchers, a robust research framework for environmental crime is required. Although some conceptual studies are available (Carter et al., 2017; Frank et al., 2019; Wright, 2011), more work is required to expound more issues on environmental crime and develop theoretical frameworks. Comprehensive research that addresses environmental crime specifically is needed.

Figure 8 displays the trending topics in this research field from 2007 to 2021. Utilizing the RStudio, generates the period within which the author keyword trended. From 2007 to 2010 and with the further impact felt till 2014, topics like the *endangered species act, water pollution* and *environmental management* started to trend with search terms of frequency 100 and below. *Environmental law* had a great trend after 2017, with a search term frequency of 200 and above. This can be associated with the Paris Agreement concluded in 2015, and several researchers were exploring it. R*enewable energy, climate change, law and environmental regulations* are trending topics in this study. Hence, more research should be conducted on these topics to explore their contributions to current discussions on environmental crime. The trending topics from 2005 to 2022 suggest the importance researchers have attached to environmental crime research.

CONCLUSION

In this research, the researchers examined environmental crime while identifying the directions for a possible future. The authors examined the publication trends by analyzing the publication years, authors, countries, and institutions that have contributed to this field. The most influential research and authors were further identified by mapping citation and co-authorship networks.

The researchers also mapped the intellectual construct of this field by identifying the most prevalent themes and intellectual construct using co-occurrence and co-citation analyses to assist researchers in developing this research field. Utilizing the bibliometric and content analysis with software like the CiteSpace and RStudio, this research provided a comprehensive review of environmental crime.

Figure 8: Trending Topics
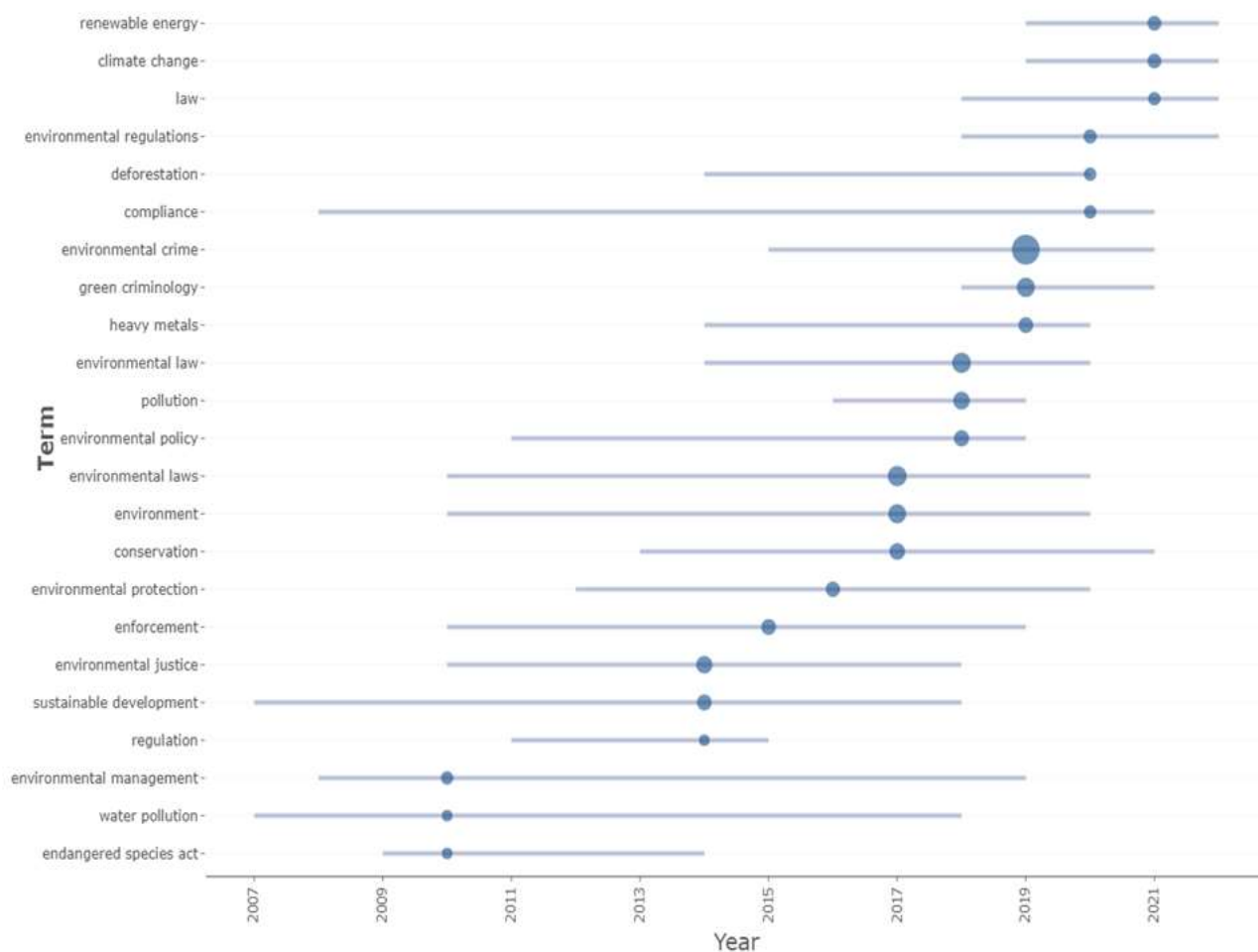
The researchers identified some limitations of this present study and the field of environmental crime and suggested possible research directions for the future. The research, like any other research was not devoid of limitations. The WoS Core Collections, where the dataset was gathered, started from 2004 to 2022 and excluded articles not written in English. The keyword selection is based on our literature review and definition of environmental crime. Other keywords could emerge in the future.

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