A bibliometric analysis and visualization of environmental damage research from 2000 to 2018

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Abstract. In recent years, the frequent eruptions of environmental pollution and environmental damage have caused great damage to the human life, property and the ecological environment, so more and more attention has been paid to the research on environmental damage. The study of environmental damage involves many disciplines, such as law, theoretical economics, applied economics, environmental science and engineering, political science, and so on. It is a comprehensive field of integration. In this paper, we used co-occurrence visualization analysis technology to make a detailed analysis of more than 1000 documents of Web of Science database. The co-occurrence of keywords can directly reflect the research hotspots in the field. Finally, we use the index of "emergence rate" to analyze the feasible direction of future research to provide references for future research.

Keywords. Environmental damage; Bibliometric analysis; CiteSpace V; review.

1. Introduction
With the rapid development of the economy and the increasing demand for human material, large-scale environmental pollution has caused the deterioration of the earth's local environment. The ecological environment damage, such as the typical ecosystem structure and function degradation caused by human activities, the decrease of ecosystem services, the rapid decrease of ecological resources, the decrease of the sustainable ability of the world economy, has seriously caused great damage to human life, property and ecological environment. Environmental damage refers to the adverse effects of environmental pollution caused by human activities, including personal health, social economy, natural resources and other aspects. The study of environmental damage involves the environmental economy, environmental chemistry, environmental health and other fields, with the characteristics of sociality and complexity [1]. Therefore, how to accurately quantify the losses caused by environmental pollution has aroused heated discussions in academic circles. The research of our country began in 1980s, in which the concept of environmental damage was put forward. And then in the new century, it developed rapidly. As countries launched the strategy of environmental protection practice in succession, the research in 2015 reached the hottest. Therefore, it is important to distinguish the development process of the field.
of environmental damage, summarize the current situation and hot spot of environmental damage research and explore the developing trend of future research and finally hope to provide references for the later research.

With the continuous improvement and development of information technology, the statistical analysis of data has been improved. Visual analysis technology plays an important role in the analysis of data, discovery of laws and decision making. The visual analysis of Citespace is mainly based on the Co-citation analysis theory and pathfinder network scaling (PF-NET), measuring the collection or literature from a certain field and exploring the key paths and turning points in the field of the subject, so as to create a potential dynamic mechanism and find the hot topics by drawing a visual map [2, 3]. In recent years, there has been a great increase in the number of research papers on environmental damage, and the review of this kind of research is relatively few. To avoid repeated research and determine the more valuable research direction, it is very important to summarize the present studies in the field of environmental damage. Obviously, it’s difficult to get an objective summary by the traditional method of analysis. Therefore, this paper uses the visualization analysis method to comb the existing literature and get a more visual and accurate results to the development of environmental damage, research hotspots and future trends.

2. Data sources and Methods
Environmental damage refers to the adverse effects of environmental damage on personal health, social economy, natural resources and other aspects, [4]. The study of environmental damage involves many disciplines, such as law, theoretical economics, applied economics, environmental science and engineering, political science, and so on. It is a comprehensive field of integration. The data analyzed in this paper were all derived from the core collection database of "Web of Science", limiting the subject term "environmental damage", and the time span “2000-2018” with documents selection "all document types" to taking the advanced retrieval. Total number of documents was 1325, from which these documents were screened and eliminated. Finally it was 1128 useful documents obtaining that persevered by the plain text for the later detailed analysis. The process of data querying, screening and finishing was captured from March 10, 2018 to March 20, 2018. The Web of Science database contains international authoritative periodicals, and the academic influence of their researches is greater. So the results of the analysis were more objective and accurate.

Citespace is one of the most distinctive and influential scientific maps and knowledge visualization software [5], which provides a new method [6] for document processing and analysis through analyzing data, scientific map and drawing visual structure maps. Based on this method, it reveals the hot spots and trends of a subject or field in a certain period. At present, it has been widely used in Library and information management, management science and engineering, public management and business management, education, sociology, physical education, basic medicine and biology [7-9], and is spreading to engineering technology. Based on the frequency of subjects (subject, author, organization, key words, etc.), and their common occurrences, such as centrality and other indicators to determine and grasp the hot spots and trends in a certain field. The visualization analysis in this study was carried out in Citespace V.

3. Results and discussion

3.1. The references co-citation analysis of authoritative research on Environmental damage
The documents co citation analysis could intuitively get the authoritative and highly cited papers in a certain field, which showed that the research results of the author or team have powerful influence and had played an important role in the research of environmental damage. The specific visualization analysis map and important node information were shown in Figure 1 and table 1 respectively. Each node was represented by 1 document, the size of the node was the proportional to the citation frequency of the literature, and the node connection represented the co-citation intensity. The thicker the connection was, the closer the relationship between the documents was.
In order to identify the most influential documents in the field of environmental damage research, this paper selected the top 5 papers with the most citations. Table 1 showed the title, periodical, year and frequency of the highly cited documents.

**Table 1.** The top 5 papers with the most citations.

| Title                                                                 | Journal                  | Year | Citation |
|-----------------------------------------------------------------------|--------------------------|------|----------|
| CO emissions, energy consumption, and output in France                 | Energy Policy            | 2007 | 451      |
| Energy consumption and economic growth in Central America: Evidence from a panel cointegration and error correction model | Energy Economics         | 2009 | 394      |
| Renewable energy consumption and economic growth: Evidence from a panel of OECD countries | Energy Policy            | 2010 | 259      |
| On the relationship between energy consumption, CO2 emissions and economic growth in Europe | Energy                  | 2010 | 235      |
| The impacts of transport energy consumption, foreign direct investment and income on CO2 emissions in ASEAN-5 economies | Renewable & Sustainable Energy Reviews | 2013 | 56       |

The paper written by Ang [10] ranked first with 451 citations. And the work of Acaravci [11] and Chandran [12] occupied the fourth and fifth position. These three papers studied the impact of gas emission on the surrounding environment, including the relationship between energy consumption and...
economic growth. Five of all these five literatures discuss the relationship between energy consumption and social economy from different angles [13, 14]. Moreover, the paper written by Verma [15] with high citations studied the environmental damage about wastewater caused by textile industry. Adverse technologies and practices in agriculture had affected the environment and human health directly [16]. Therefore, it’s essential to assess the energy consumption and environmental pollution.

3.2. The Keywords Analysis of Research Hotspots on Environmental Damage Study
The 1128 data derived from Web of Science are selected as the research samples, and the key words were selected as the display nodes. The connections between the nodes represented the time of the first co-occurrence of the key words, and the size of the nodes was directly proportional to the frequency of the occurrence of the nodes. The common knowledge map was shown in Figure 1. In general, the higher the frequency of the key words, the greater the influence, and the central character of more than 0.1 was more influential, which meant more the researches relating these key words, indicating these key words had more important significance.

From Figure 2 and table 2, there are 196 nodes and 658 connections, representing 196 key words. Because the retrieval word was "environmental damage", two most frequent words "environmental" and
"damage" in high frequency words should be removed. And the words “Model, impact, climate change, management, system, policy, sustainability, emission, pollution, energy” were the key words that appeared in the first ten of the frequency, suggesting that all of them are the focus of current environmental damage research. At the same time, key words “carbon, growth, emissions, soil” showed high centrality, which were 0.13, 0.12, 0.11 and 0.11, indicating that this node was an important node in the co-occurrence network. Then this paper analysed these key words from the following two aspects.

Table 2. High-frequency keywords of environmental damage research from 2000 to 2018

| Number | Keywords            | Frequency | Centrality |
|--------|---------------------|-----------|------------|
| 1      | management          | 55        | 0.17       |
| 2      | carbon              | 12        | 0.13       |
| 3      | sustainability      | 29        | 0.13       |
| 4      | growth              | 23        | 0.12       |
| 5      | climate change      | 60        | 0.11       |
| 6      | emission            | 48        | 0.11       |
| 7      | industry            | 10        | 0.10       |
| 8      | cost                | 9         | 0.10       |
| 9      | International trade | 9         | 0.09       |
| 10     | technology          | 9         | 0.09       |

From the perspective of research, the study of environmental damage involved many disciplines, such as law, theoretical economics, applied economics, environmental science and engineering, political science, and so on. It was a comprehensive field of integration. Combining frequency and centrality of key words, summarization could be made from the following angles. From the perspective of economics, it was mainly about the economic evaluation of environmental damage, including the following key words: “industry”, “cost”, “risk” “sustainability” “economic growth” “international trade” “consumption” “management”. By quantifying the comprehensive loss caused by pollution to people's health, property and the environment itself, it would promote the use of economic means to improve the management and control of environmental damage, and then achieving sustainable development. At present, it seemed that there was no recognized and unified system for the quantitative economic assessment of environmental damage. Due to different environmental problems faced by different countries and countermeasures taken by them, there were great differences in the assessment of environmental damage. From angle of environmental science and engineering, the research was mainly about the study of damage to environmental medium itself, including “carbon emission”, “soil”, “water” and so on. Environmental damage was generated through environmental media. Pollution would affect the health of people living in the environment through environmental media, and also do harm to production. It was noteworthy that the key words "heavy metal" appear sixteen times and its centrality is 0.08, indicating that it was gradually becoming research hotspot. Heavy metal was one of the key pollution factors that lead to environmental damage. In addition, there were various kinds of organic and inorganic substances. It could be seen that the research on environmental damage showed the development trend from macro to micro, and the research was more in-depth. From the angle of jurisprudence, the word "policy" appeared 41 times, including environmental damage assessment and liability system. Undoubtedly, legal was an important means to deal with environmental damage. In the early years of the study, some pertinent laws had emerged, such as “Convention on oil pollution responsibility” in 1969, “oil pollution fund convention” in 1971, and “white paper on environmental civil liability”, which was promulgated in 2000, which made it clear that "environmental damage not only included the damage to human, property and site pollution, but also damages to nature, especially those from creatures. The viewpoint of diversity protection was very important for natural resources.
And the solution to environmental damage had been upgraded from civil law to specific laws and regulations.

From the perspective of research methods, there was no unified method and theory at present. The research methods of environmental damage mainly include equivalent analysis method and environmental value evaluation method, including resource equivalence analysis method, service equivalence analysis method, value equivalent analysis method, market value method and benefit transfer method. Many scholars in developed countries such as Europe and America developed a number of quantitative and theoretical models which were suitable for various countries. The method of assessment for natural resource damage was changed from the past based on the monetization to the equivalent analysis based on the basic recovery cost, and had been widely used [17,18]. In the context of environmental baseline recovery, the environmental damage assessment guidelines issued by the United States Department of the interior (DOI) and the oceanic and Atmospheric Administration (NOAA) included the loss of services provided by natural resources as a result of the assessment and taking restoration of contaminated environmental resources to the baseline state of the region as a primary goal and final scheme [19]. In terms of the causal relationship identification and damage quantification of environmental damage, the relevant laws in the United States clearly stipulated that the necessary connection between the leakage of the pollutants and the environmental damage must be proved in the case of environmental pollution cases, and the natural resource damage caused by pollution must be quantified, and three schemes including main recovery, supplementary recovery and compensatory recovery were adopted in the recovery stage. The co-occurrence knowledge map showed that "model" appears 72 times, with the highest frequency. The frequency of "optimization" and "uncertainty" were 18 and 13, respectively. The results showed that Optimization was the mainstream method in current research. As environmental damage involves physical health, environment itself, social public rights and other aspects, there were many uncertain factors involved in the emergency stage, pollution restoration stage and ecological restoration stage after the occurrence of pollution events. “Uncertainty” first appeared in 2006 and was continuously optimized. The traditional monetization value method was transformed into an uncertain research method.

Generally speaking, interpenetration in the perspective of research was among different disciplines, including jurisprudence, economics, environmental science and so on, then multidisciplinary cross topics were constantly derived, indicating that environmental damage was not a simple problem in a single field, but a comprehensive field of multidisciplinary integration. The research method was also transformed from traditional monetization value evaluation method to fuzzy uncertainty optimization method, becoming more scientific.

3.3. The burst of research front on Environmental Damage Study

The significance of this paper was to explore the feasible direction of future research. This paper used the rate of burst to represent it. Burst rate showed the frequency change rate of the research object (keyword). Compared with frequency and centrality, it was more accurate to describe the future development trend. High rate key words were shown in Table 2.

### Table 3. High-burst keywords of environmental damage research from 2000 to 2018

| Number | Keyword             | Burst | freq | centrality |
|--------|---------------------|-------|------|------------|
| 1      | industry            | 3.58  | 7    | 0.1        |
| 2      | air pollution       | 3.45  | 7    | 0.03       |
| 3      | emission            | 3.28  | 48   | 0.05       |
| 4      | ecosystem service   | 3.25  | 17   | 0.03       |
| 5      | quality             | 3.14  | 13   | 0.02       |
It could be seen from table 3, “industry”, “air pollution”, “emission”, “ecosystem service”, “quality” were high emergence rate key words, and the burst both higher than 3, and taken as the feasible direction analysis of future research. The rapid development of industrialization led to frequent environmental damage and great losses to peoples’ health, property and society. Many researchers applied environmental damage to the field of industrialization, which was more pertinent. In addition, uncontrolled discharging of domestic sewage and industrial waste water led to air pollution, which affected ecological balance and destroys the function of ecological service, which eventually led to the decline in quality of people's life and environment, which was not conducive to the harmony and stability of the society. The future research would continue to study the environmental pollution, especially the air pollution damage under the background of industrial development, focusing on the ecological system (environmental resources), to improve the quality of the ecological environment and the quality of human life.

4. Conclusion
In the era of big data, the promotion and application of knowledge map has greatly helped document analysis and arrangement. This paper first retrieved the related papers of environmental damage research from the core database of Web of Science, screening and determining the analysis data samples, then introducing them into the CiteSpace V for Visualization analysis of co-occurrence, mainly aiming at the analysis of key words. The hot spots in the field of emergency logistics were discussed by the visual analysis of the citation, then possible future research and development parties were reasonably predicted too.

The citation analysis showed that environmental damage was closely related to economic growth. At present, the highly cited documents mainly included the influence of air and water pollutions on the environment, social economy and human health. In the future, researchers could focus on the quantitative assessment of environmental damage according to the classic papers presented in this paper. Under the circumstances of keyword visualization analysis, research angles could interpenetrate in different disciplines, including jurisprudence, economics, environmental science and so on, and continued to derive multidisciplinary cross topics, indicating that environmental damage was not only a simple problem in a single field, but also a comprehensive field of multidisciplinary integration. The research method was also more scientific transferring from traditional monetization value evaluation method to the fuzzy uncertainty optimization method. There were some progresses in legislation and accountability of environmental damage assessment, but still needed a universally recognized evaluation system and method. At the same time, from the analysis of the burst rate, it was the main trend of future research to study the environmental pollution, especially the air pollution damage, focusing on the ecological system (environmental resources), improving the quality of the ecological environment and human life. Generally speaking, the research on environmental damage made great progress in recent years, and in the future, the research were more likely to change from theoretical research to practical application.

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