Bibliometric Analysis of Carbon Accounting Research

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ABSTRACT

The issue of the environment continues to receive special attention from researchers. This is related to business operations' importance in paying attention to the profit aspect and environmental impacts to maintain the surrounding environment. Therefore, activities that affect carbon emissions must be reported annually. This is called carbon accounting. This study aims to map carbon accounting articles for 2012 to 2021 on the dimensions.ai database. Using the keyword "carbon accounting," the collected data was 500 articles. The study results found that the journal most relevant to carbon accounting is "The Science of the Total Environment". Meanwhile, the journals that have the most significant impact are "Global Change Biology," "Scientific Reports," and "The Science of the Total Environment." Meanwhile, the most productive journal is "The Science of the Total Environment," followed by "Environmental Science and Pollution Research." The most relevant and prolific authors were Wang Y, followed by Zhang Y and Zhang X. In addition, Wang Y and Zhang X were the authors who had the greatest impact. The distribution of words in articles with the theme of carbon accounting is dominated by "carbon" and "accounting." This research shows that the theme is undergoing good development. Research data shows that the word "carbon" is rapidly from 2012 to 2021. This study predicts that articles on carbon accounting will continue to increase in the years to come, especially the themes of "emissions" and "study" which have high development although their relevance is quite low. The development of research on carbon accounting is closely related to environmental issues which are currently being studied by many researchers, especially to achieve sustainable development goals.

Keywords: Carbon accounting, Bibliometric, R
JEL Classifications: M41, Q54, L60

1. INTRODUCTION

Currently, the disease experienced by the earth is global warming caused by climate change. One of the causes of global warming is extreme weather changes. This is because the concentration of greenhouse gases increases on this earth. One of them is because the company's industrial activities (Sullivan and Gouldson, 2013) are not well controlled. Activities in industry always require a very large amount of energy, such as energy that comes from oil and gas.

Discussion about global warming is an essential material for a country. So, currently, global warming is a business problem, but it has become part of a political problem (Choi et al., 2013). This is evident from the number of political leaders who firmly commanded for business people to pay attention to the problem of global warming (Hapsoro and Ambarwati, 2018).

Disclosure of carbon emissions is one of the environmental disclosures companies must carry out. To communicate the company's activities related to carbon emissions caused by its business activities, disclosure is required in its business report. This is voluntary (Cotter and Najjah, 2011; Andrew and Cortese, 2011).

If companies do not disclose carbon emissions in their financial statements and annual reports, information asymmetry will occur. Disclosure made by the company is called carbon accounting, which is expected to give a good image to the company's business because it has a responsibility to the environment. This must be

the company's commitment and following signaling theory. This disclosure requires appropriate incentives even though voluntary (Hapsoro, 2006).

Many researchers have studied the issue of carbon disclosure because it is considered very important for the development of accounting. In addition, the contribution of researchers in overcoming global warming can be given in the form of research results published in research journals in the world. However, there has been no good mapping of carbon accounting research articles.

Research with the aim of mapping articles is called bibliometrics. Therefore, we intend to map research on carbon accounting. Next we will map by author name, journal name, correspondence, affiliation, keywords, and related topics.

2. LITERATURE REVIEW

2.1. Carbon Emission Disclosure
Carbon emissions are gases released into the atmosphere from the combustion of carbon compounds, such as CO_2, diesel, and other fuels. Ecolife (2011) confirms that the release of carbon into the atmosphere is directly correlated with the release of carbon dioxide. Gullison et al. (2007) explained that the countries that produce the largest carbon dioxide (CO_2) emissions in the world are China, the United States, and Indonesia.

Carbon emissions are a contributor to climate change along with greenhouse gas emissions. Excessive gas emissions can cause global warming or the greenhouse effect. This results in a significant increase in Earth's temperature. Therefore, an entity needs to understand its business activities' impact on the surrounding environment. So that the entity needs to communicate its activities to the community for its business that results in global warming due to carbon emissions (Choi et al., 2013). The Kyoto Protocol emphasizes the importance of carbon accounting because companies are obliged to document and disclose their carbon emissions (Irwhantoko and Basuki, 2016).

Najah (2012), defines carbon disclosure as information presented by the company, both qualitatively and quantitatively related to the level of carbon emissions of the company. The disclosure is an implication of the risk of its activities that impact climate change, and will impact the future of the environment. Therefore, all efforts made by the company in reducing carbon emissions must also be disclosed in the company report (Jannah and Muid, 2014). Ennis et al. (2012) explained that stakeholders will be facilitated in making decisions on the company's performance related to carbon emissions to reduce carbon emissions

2.2. Carbon Accounting
Accounting has a special role in the environment. Even Hopwood (2009) suspects that accounting will have a further role in environmental issues in the future. Accounting will report any activities that have an impact on the environment. This is part of its contribution to achieving the sustainable development goals (SDGs). Accounting also plays a role in all stakeholders

including the government in assessing the business impact of a company so that the government will be facilitated in assessing the company's performance for its concern for the surrounding environment. The entity will communicate changes that occur in nature through environmental disclosures. So that the flow of information continues to increase from year to year.

Carbon Accounting is a report that discusses climate change mitigation into accounting (KPMG, 2008; Hespenheide et al., 2010). Disclosure of carbon emissions or calculating carbon costs is a part that must be reported in the company's business activities. Carbon accounting is part of accounting, as is the calculation of environmental costs that arise from the calculation itself (Schaltegger and Burritt, 2000). However, carbon accounting is more specific to carbon disclosure. Schaltegger and Burritt (2000) define environmental accounting as part of accounting that discusses the impact of a company or factory on the environment. In addition, environmental accounting discusses financial aspects and non-financial aspects (Burritt et al., 2002), so that environmental accounting is more general in nature. In financial accounting, costs related to the environment will be included in the components of the financial statements, so that they become part of environmental accounting. In management accounting, the company will identify and report information on management activities related to product lines, divisions, and systems used (Stechemesser and Guenther, 2012). All of them can have a relationship with the environment.

3. METHODOLOGY

This study uses the bibliometric method with the aim of mapping research on carbon accounting. This method will provide an overview of the author's mapping, source, impact, frequently occurring words, affiliations, and others. Usually, bibliometric research provides map construction through visualization and a map representation. The biggest concern of this research is mainly on the construction of the map with different mapping techniques. Although bibliometric research has received less attention, many researchers have begun to focus on bibliometric representations in the form of graphics (Chen, 2003; Firmansyah and Rusydiana, 2021) even though they rely on software to build graphical representations.

Research using R Studio software is to facilitate mapping through simple visualization. Although the articles collected are quite a lot, this software can present simple outputs making it easier for researchers to analyze them. The articles collected were 500 documents from the dimensions.ai database with the keyword used, namely "carbon accounting" in the 2012 to 2021 publication period.

4. RESULT

Based on the articles collected, we present data by year of publication, the number of articles published at that time, and the number of citations for each article that discusses the theme of carbon accounting. Table 1 presents the average article citations,

Table 1: Total citations

Year	N	Mean TC per article	Mean TC per year	Citable years
2012	21	76.48	7.65	10
2013	22	43.55	4.84	9
2014	24	40.33	5.04	8
2015	24	59.42	8.49	7
2016	41	36.51	6.09	6
2017	30	45.90	9.18	5
2018	27	33.78	8.44	4
2019	82	18.52	6.17	3
2020	113	12.42	6.21	2
2021	116	3.30	3.30	1
Total	500	370.20	65.1	

Figure 1: Three fields plot

Figure 2: Most relevant sources

based on the average citation per year and the average citation per article, over 10 years, from 2012 to 2021.

Usually, articles referenced a lot indicate the article has good quality, both in terms of substance quality and the quality of the journal that published it (Ebrahim et al., 2013). Table 1 shows that the most publications of papers related to the theme of Carbon Accounting are in 2021 with 116 documents published. Then, based on the average total citations for each article, the highest citations occurred in articles published in 2021 with an average of 3.30 citations and the highest average citations occurred in 2012 as many as 76.48 citations.

4.1. Three Fields Plot

The Three Fields Plot is an illustration consisting of 3 elements: the author's name, the journal's name, and the topic. The three elements are connected by a gray plot related to one another. Starting with the author's name, each author shows his contribution to the journal, then each journal shows topics that are often published for research on carbon accounting. The rectangle size describes the number of publications associated with each element.

From Figure 1, it is known that in the first element, there are 20 authors detected in the Three Fields Plot who publish articles with the theme of carbon accounting. The author who contributed the most was Wang Y who wrote in 6 different journals depicted in gray lines. Meanwhile, the journals that contributed the most were global change biology and The Science of the Total Environment, followed by Environmental Science and Pollution Research. In addition, of the 20 topics detected in the Three Fields Plot, the most widely used topics are cabon, carbon dioxide, and China.

4.2. Most Relevant Sources

Figure 2 shows the number of research documents published by each journal based on their level of relevance to the theme of Carbon Accounting. The data shows that the list of the names of the top journals that publish the most carbon accounting themes. The darker the blue color indicates the greater the quantity and relevance to the research theme, the number of documents published by all journals ranges from 4 to more than 54 documents.

20 journals were detected to be most relevant to the theme of carbon accounting. The journal in the top position is The Science

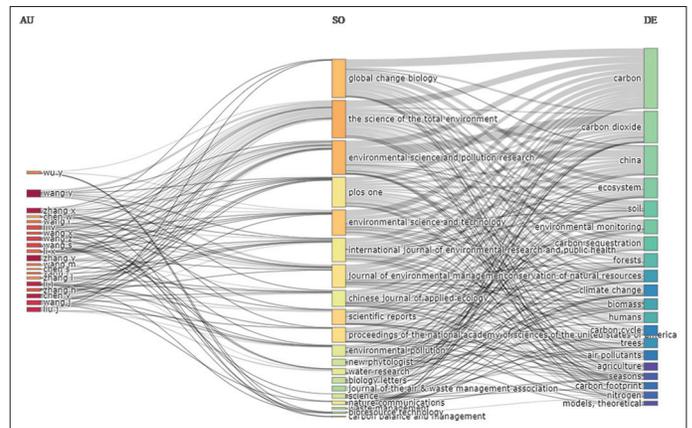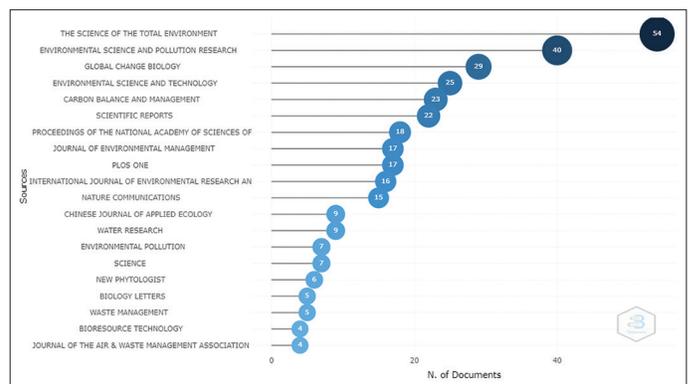of the total environment with a total of 54 published documents which are shown in blue bar charts and dark circles compared to other journal bars. This is because the journal is very relevant to the themes discussed. As for the journals in the lowest position with the number of publications 4, there are 2 journals marked in blue with bright circles. In terms of quantity and relevance to the theme of carbon accounting is still lacking.

4.3. Source Impact

Journal calculation is not only based on the quantity produced or its relevance. However, this research was also carried out based on each journal's impact that publishes a paper with the theme of accounting carbon by calculating the journal's h_Index, and is depicted in a blue bar chart. The darker the blue on the chart, the bigger the impact.

From Figure 3, Global Change Biology occupies the top position with an h-Index of 17. While the second place is Scientific Reports with an h_index value of 16. The lowest h_index score is 3 in the bottom 4 journals.

4.4. Source Growth

This study also discusses the development of journals that are sources of research on the theme of Carbon Accounting. Figure 4 shows the annual occurrence of each journal from 2012 to 2021. The curve illustrates that study with the theme of Carbon Accounting tends to increase in publication. Significant increases occurred from 2019 to 2021, especially in "The Science of The
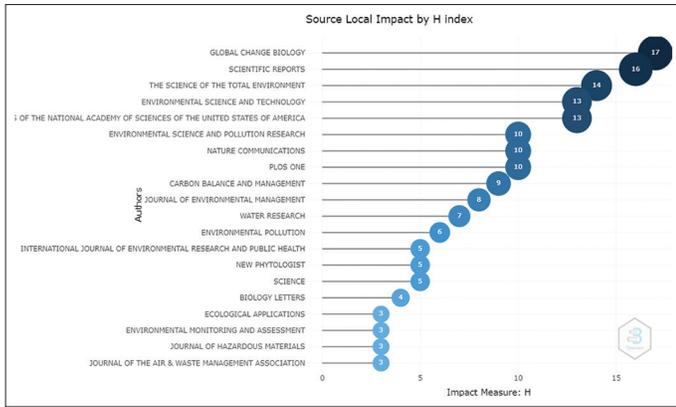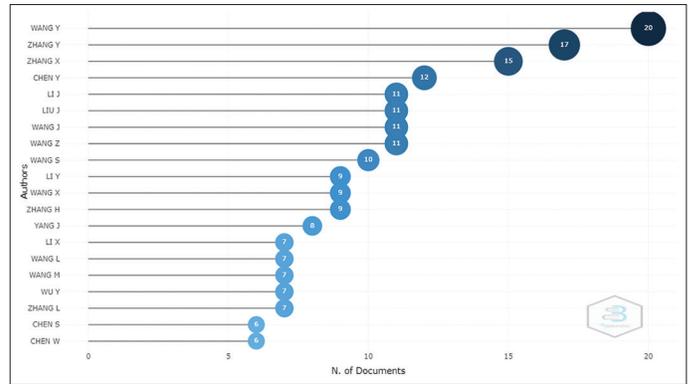
Figure 3: Source impact

Figure 4: Source growth

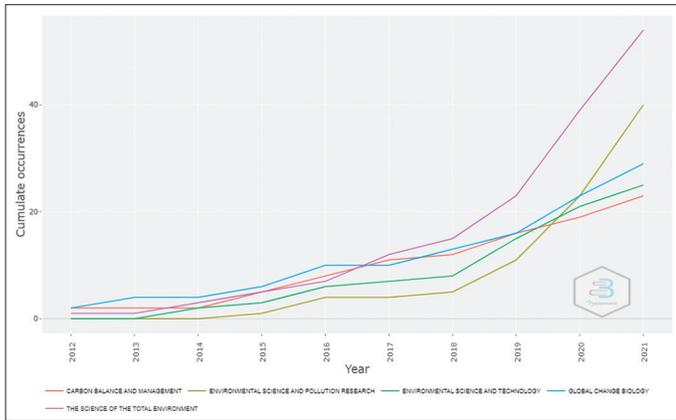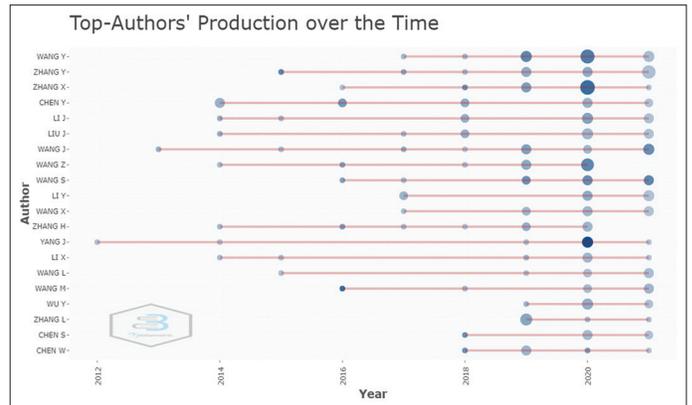

Figure 5: Most relevant author

Figure 6: Top author's productivity

Total Environment" and "Environmental Science and Pollution Research."

4.5. Most Relevant Author

Authors who have published their papers can also be ranked based on their relevance to the research theme of carbon accounting based on the number of articles published. The number of articles by each author ranges from 6 to 20. The number of articles produced by the author is indicated by an extended diagram with a dark blue circle. Where from Figure 5 shows that the author with the most articles was obtained by Wang Y who had 20 articles, Zhang Y who had 17 articles, Zhang X who had 15 articles, and other authors who had fewer articles.

4.6. Top Author's Productivity

Productivity can not only be measured in published journals, but also on authors in particular. Figure 6 shows the productivity of some of the top authors during the research period, namely in 2012 to 2021. A red line indicates this productivity from the beginning of the author publishing his research until the last year the author was recorded to publish his research. In addition, the circle in the red line shows the number of papers published according to the applicable year.

Figure 6 presents an overview of the productivity of authors who have written research related to Carbon Accounting. The author who

published research related to carbon accounting in 2012 is Yang J and has been productive until 2021. Yang J is the author who has the longest period in researching this theme. Meanwhile, the author who publishes the most articles on this theme is Wang Y, who published 18 articles. However, Wang Y does not have a long track record researching this theme, only from 2017. But his productivity is evident from his publications which reached 8 times in 2020.

4.7. Author Impact

Authors who have published their papers can also be sorted by impact based on the h-Index. The magnitude of the impact produced by the author is indicated by the length of the diagram and the blue circle. The author's h-Index value ranges from 4 to 8. The picture above shows 2 authors with an h-Index score of 8, the highest value marked in dark blue, which describes the greatest impact, namely Wang Y and Zhang X. The other 18 authors have an h_index score of 4 to 7 (Figure 7).

4.8. Word and Thematic

Next, the words that often appear in the data collection of articles researched on the carbon accounting theme will be displayed in the form of a Word Cloud.

Word Cloud describes words that often appear in the data collection of articles studied in the carbon accounting theme. Word cloud displays an image of words with various sizes according to the number of words that appear. The location of the words tends to be random but the words that dominate are placed in the middle

so that they are more visible with a large size. Based on Figure 8, the word Carbon is the one that appears the most in the carbon accounting theme, while in second place is the word Emissions, and the third is the word accounting.

4.9. Word Growth

In this study, the words that often appear are also described in a year's development curve with a cumulative occurrences value. These results show the average number of these words in the data collection studied in the carbon accounting theme per year. Figure 9 shows most words that appear and are used frequently since 2012. The Figure 9 clearly shows that the word Carbon is the most used every year and with a very significant increase, so it is very different from the appearance of other words such as emission and forest

4.10. Trend Topics

Topic trends are also an important part of this research, where Figure 10 shows the development of topics from time to time every year. So that it is known what topics have been used for a long time and what topics have been used recently. The topic's appearance is also adjusted to the frequency of the quantity of the word appearing in the research on the carbon accounting theme. The bigger the blue circle, the more the word was used and the more to the right the more recently the word was used.

Based on Figure 10, only three topics were used in 2013: greenhouse, fine, and comparison. The greenhouse and fine topics

were the longest used topics, and were detected from 2013 to 2020. The most widely used topics were Carbon with a peak in 2019. Meanwhile, the most recently used topics until the end of 2021 were land, footprint, system, chemical, and characteristics.

4.11. Co-occurrence Network

Next is the Co-occurrence network which displays words in colored circles by considering the relationship between one word. Clusters with the same color indicate that the words are interconnected, while the size of the circle indicates the magnitude of the relationship between words. Based on Figure 11, the words carbon, accounting, emissions, study, and result are the words that have the most relationships with other words in articles with the theme of carbon accounting.

4.12. Thematic Map

This article also analyzes the thematic map based on density and centrality, divided into 4 quadrants. These results are obtained from a semi-automatic algorithm by reviewing the titles of all references to the object of research with relevant keywords other than the author's keywords so that the results can capture deeper variations.

The upper right quadrant is a driving theme which is characterized by high density and centrality, so it needs to be developed and is important to be studied in further research. There are no words detected in this quadrant, because they are on the downward

Figure 9: Word growth
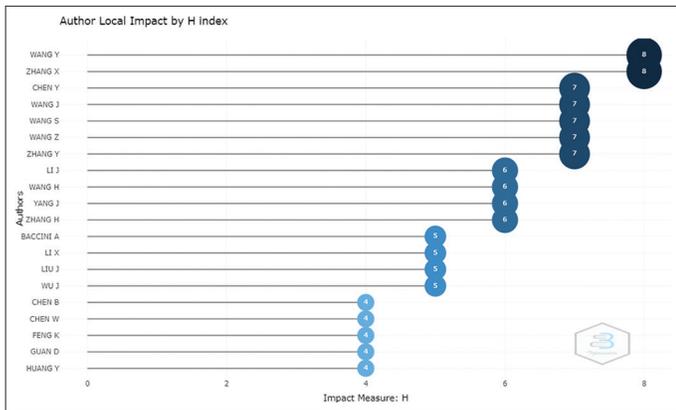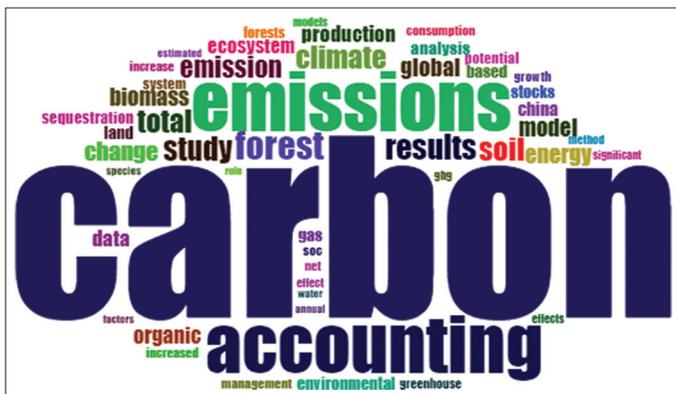
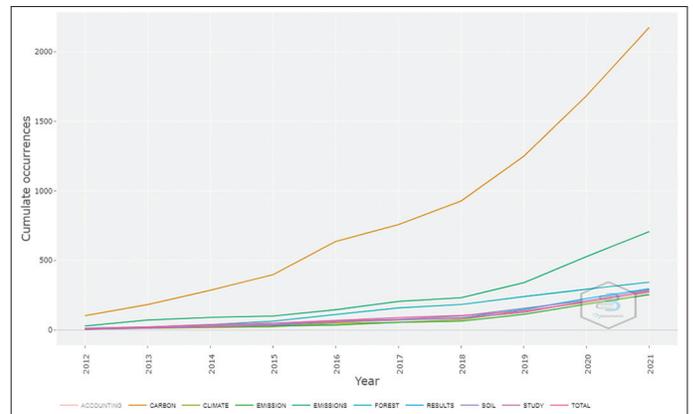**Figure 7:** Author Impact

Figure 8: Word cloud
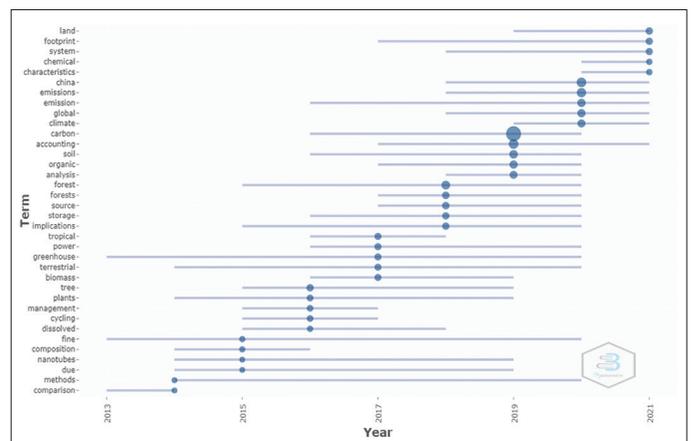
Figure 10: Trend topics
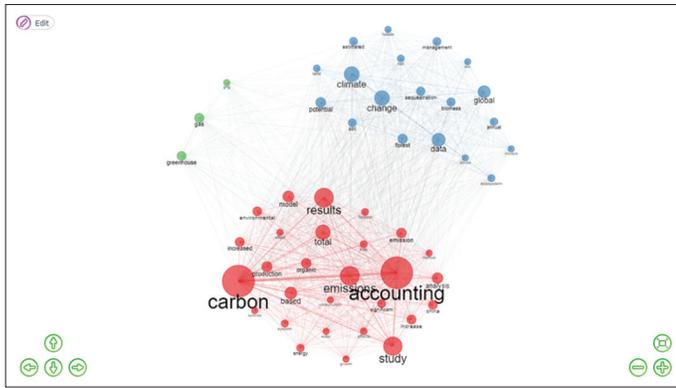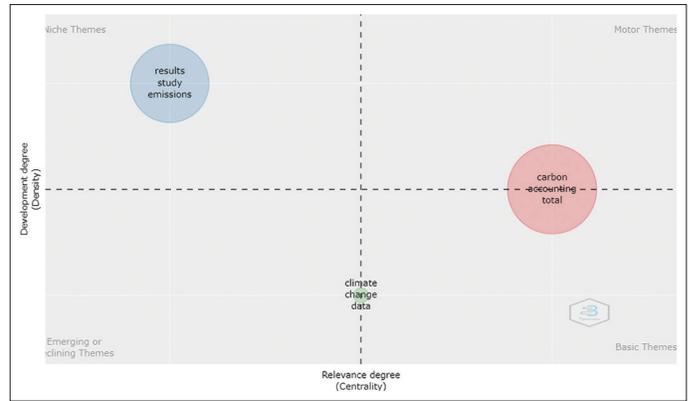
Figure 11: Co-occurrence network
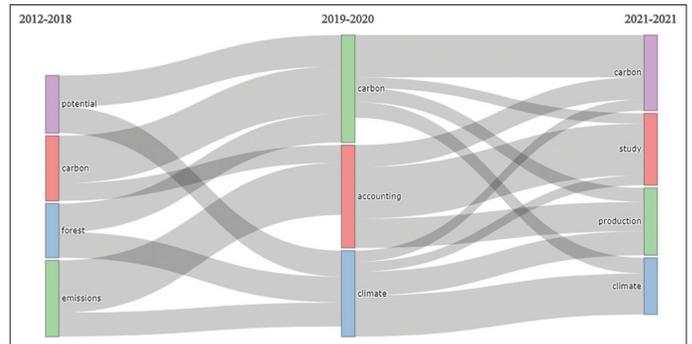

Figure 12: Thematic map

line which indicates that the density has almost decreased. The words are carbon, accounting, and total. Furthermore, the upper left quadrant shows specific and rare themes but has high development, indicated by high density but low centrality. The themes in this quadrant are results, study, and emissions (Figure 12).

Furthermore, some themes have been used in the lower left quadrant for a long time but are experiencing a declining trend with a marked low centrality. In this quadrant, it was detected that the climate, change, and data themes had decreased but were in the middle line which indicated an increase. While the lower right quadrant is the basic theme characterized by high centrality but low density. These themes are important to be included in the research because they are general topics that are commonly used. There is no clear theme in this quadrant, but it is in the middle line between the bottom and the top.

4.13. Thematic Evolution
The theme in the article on carbon accounting continues to develop. This can be seen in the change in the theme used based on the thematic evolution diagram presented by the R software. Although the theme of this research is carbon accounting, this data shows that several sub-themes are quite widely used. The left section shows several themes that were widely used from 2012 to 2018, there are four listed themes with different sizes depending on the quantity of use of these themes. The theme of carbon and emission was the most widely used in that period. The middle section shows several themes widely used from 2019 to 2020. Several themes that emerged in this period were an evolution of the previously used themes and were related in the discussion, such as the carbon theme which emerged due to the revolution from the potential, carbon, and forests. The right side shows the most widely used themes in 2021. There are 4 listed themes, of which carbon is the most widely used, followed by study, production, and climate (Figure 13).

5. DISCUSSION

This carbon accounting theme is closely related to the business environment. Business entities show their concern for preserving the environment, especially in achieving the Sustainable Development Goals (SDGs) by disclosing their business reports.

Figure 13: Thematic evolution

Usually, companies make such disclosures to maintain the legitimacy of the community and maintain their performance. Therefore, the company will disclose these activities.

From the data collected, namely 500 articles in the dimensions. ai database, it can be seen that articles on carbon accounting continue to develop, it is proven that every year the publication of this theme continues to grow, especially in the last three years which experienced significant developments, especially starting in 2018. However, citations from articles has not been shown much by the articles that have just published. Articles that have been published for a long time are the most cited.

The journal most relevant to articles on carbon accounting is "The Science of the Total Environment" with 54 articles published, and followed by "Environmental Science and Pollution Research" which published 40 articles. Both journals publish many relevant articles because they both focus on the environment. So that authors tend to like articles about carbon accounting to be published in journals that focus on the environment.

Of the many journals that publish articles on carbon accounting, the one that has the biggest impact is "Global Change Biology," followed by "Scientific Reports", then "The Science of the total Environment." After being traced, "Global Change Biology" is published by Wiley-Blackwell Publishing Ltd and is included in the Scopus Q1 indexed journal. So "Scientific Report" is a journal published by the Nature Publishing Group which has such a good reputation that it is indexed by Scopus Q1. Then "The Science of the Total Environment" is also a Elsevier's journal indexed by

Scopus Q1. These three journals deserve a big impact because they have good quality. So many articles on carbon accounting refer to articles published by the three journals.

During the last ten years, each journal that publishes articles on carbon accounting has continued to increase. The fastest growing journal is "The Science of the total Environment" followed by "Environmental Science and Pollution Research". They have published so many articles on carbon accounting, especially since 2019. The development of articles in these journals shows that the two journals are quite consistent in contributing to carbon research. Usually, the contribution given by the journal to the development of science is through scientific publications on certain themes whose contents can be utilized by academics, researchers, and industry practitioners. In this case, the two journals care about environmental pollution, especially the impact of carbon released by industry.

Of the many researchers most relevant in studying carbon accounting, Wang Y is the most relevant, writing as many as 20 articles over 10 years. Then Zhang Y wrote 17 articles, and Zhang X wrote 15 articles. All three have contributed the most to carbon accounting research, so many other authors have cited their writings in the world. Wang Y and Zhang X are the authors who have had the greatest impact on research on carbon accounting.

The distribution of words in the article on carbon accounting is dominated by the words "Carbon" and "accounting." In addition, other words are quite prominent, namely the word "emissions." This shows that the frequent occurrence of the word carbon in the study indicates an affirmation of the importance of the current discussion of carbon. In addition, the development of the use of the word "carbon" is very rapid from 2012 to 2021. It is very far from other words.

This research topic also has other sub-topics related to carbon accounting research. The latest topics are mostly about land, footprint, system, chemical, and characteristics. Even though this topic is being discussed in 2021, overall the topic of "carbon" is still the most discussed, especially in 2019 but stopped in 2020. Meanwhile, the topic of "accounting" persists until 2021. Many sub-topics in this study indicate many allusions to carbon accounting research with other topics.

In the end, this research can illustrate that carbon is an important theme discussed by researchers. Currently, this theme is being discussed more and more because it concerns researchers on the impact of carbon emissions released by industry. Industry makes its business reports by disclosing carbon emissions to show its concern for the environment. This condition causes researchers to be interested in studying the issue of reporting carbon disclosures, so it is often referred to as carbon accounting

6. CONCLUSSION

This research was conducted on 500 articles with the theme of carbon accounting in the dimensions.ai database from 2012 to 2021. Based on the data collected, it is known that the journal

most relevant to this is "The Science of the Total Environment," followed by "Environmental Science and Pollution Research." Meanwhile, those that have the biggest impact are "Global Change Biology," "Scientific Reports," and "The Science of the Total Environment." These three are the best journals indexed by Scopus Q1 to become references for articles. Meanwhile, the most productive journal is "The Science of the Total Environment," followed by "Environmental Science and Pollution Research."

The most relevant and productive author on the carbon accounting theme is Wang Y, followed by Zhang Y and Zhang X. Apart from being productive, Wang Y and Zhang X are the authors who have had the greatest impact on carbon accounting research.

The distribution of words in articles with the theme of carbon accounting is dominated by "carbon" and "accounting." Research data shows that the word "carbon" is rapidly from 2012 to 2021. This development is very far from other words that often appear in articles.

Seeing the trend of publication of articles on the theme of carbon accounting which continues to increase, it is predicted that this article will continue to increase in the years to come, especially the themes of "emissions" and "study" which have high development although their relevance is quite low. But this analysis shows that the theme is progressing well.

In addition, this research will be a reference for other researchers related to the up-to-date mapping of research on carbon accounting. The development of research on carbon accounting is closely related to environmental issues which are currently being studied by many researchers, especially to achieve sustainable development goals.

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