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What is Carbon Accounting?

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This study aims to see the development of research on the topic of "Carbon Accounting" and research plans that can be carried out based on journals published on the theme. This research uses a qualitative method with a bibliometric analysis approach. The data used is secondary data with the theme "Carbon Accounting" which comes from the Dimension database with a total of 18956 journal articles. Then, the data is processed and analyzed using the VosViewer application with the aim of knowing the bibliometric map of "Carbon Accounting" research development in the world. The results of the study found that there were 3 clusters with the most used words being carbon emission, emission, carbon, production, factor, change, accounting, effect, and consumption. Then, the topics of research paths related to Carbon Accounting are Carbon accounting in biomass estimation, Carbon accounting in emission reduction strategies, and Carbon accounting in Yellow River Basin development.

Keywords: Carbon Accounting; Research Map; Bibliometric

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INTRODUCTION

Climate change is a critical global issue, with increasing carbon emissions as the main driver (Kamalov & Toshpulatov, 2025). Rising carbon dioxide in the atmosphere, largely due to the increasing extraction and consumption of hydrocarbons, particularly in the metallurgical industry, contributes significantly to the greenhouse effect and subsequent global warming (Kamalov & Toshpulatov, 2025). This warming accelerates extreme weather events, rising sea levels and threats to food and water security, disproportionately affecting vulnerable populations. Moreover, the consequences of climate change span multiple sectors, affecting agriculture, food security and economies worldwide (Atanasova & Naydenov, 2025; Sandow et al., 2025).

Carbon accounting is the process of measuring, reporting, and allocating greenhouse gas emissions resulting from human activities (Kaur et al., 2023). Zhanga et al (2016) explained that carbon accounting is a management activity that provides financial information on carbon emissions with monetary and material measurements using accounting and verification methods. This process involves quantifying greenhouse gas emissions resulting from human activities, which allows organizations to make informed decisions aimed at mitigating climate change and promoting sustainable resource management (Kaur et al., 2023). It explains that carbon accounting serves as a systematic approach to measuring, tracking and managing greenhouse gas emissions across organizational and operational boundaries. It involves measuring emissions through standard methodologies such as activity-based accounting, application of emission factors (Dong et al., 2024; Qian et al., 2019), and life cycle assessment to capture direct and indirect carbon footprints (Kaur et al., 2023; Beecham, 2020).

Reporting frameworks are often aligned with international protocols (e.g., GHG Protocol) to ensure transparency, allowing entities to disclose emissions data in sustainability reports or regulatory filings (Qian et al., 2019). For management, carbon accounting informs mitigation strategies such as energy efficiency improvements, renewable energy adoption (Bao et al., 2024; Qian et al., 2019), and carbon offset initiatives, while advanced systems integrate dynamic response modeling and multi-energy optimization to balance economic and environmental objectives (Bao et al., 2024). Challenges include regional variability in emission factors (Dong et al., 2024), data granularity requirements, and the risk of reducing ecological impacts to commoditized metrics (Martineau & Lafontaine, 2020), which require context-aware frameworks that reconcile technical precision with ecological stewardship (Kaur et al., 2023).

As carbon emissions are increasingly scrutinized in the context of global climate goals, carbon accounting frameworks have evolved to address the complexity and heterogeneity of practices across different sectors. These frameworks facilitate transparency and accountability in emissions reporting, allowing stakeholders to assess their carbon footprint and effectively implement strategies for reduction. By providing a standardized methodology for tracking emissions, carbon accounting plays an important role in encouraging responsible environmental management and supporting international climate agreements. Xiao (2024) emphasized accurate accounting of industrial carbon emissions is essential under the new system requirement of "dual control" of total carbon emissions and intensity.

Based on this background, it is important to see the extent of the current development of *Carbon Accounting* through research, and one method that can be used to see the development of research is bibliometrics using VosViewer. The method is able to create and display author journal maps and research paths based on co-citation data or keyword maps based on co-incidence data. Some research that examines related to *Carbon Accounting*, namely Chen et al (2021) analyzed the evolution and structure of carbon footprint (CF) studies using a bibliometric approach on 9,848 literature records from Web of Science. This study identified key areas of CF research, significant international collaborations, and emerging topics such as CF accounting methods and the impact of food consumption on climate change, highlighting the unique characteristics and future directions of CF research.

Yin et al (2022) reviewed 662 articles on urban carbon accounting over the past three decades, highlighting the evolution of research themes and methodologies used to measure CO2 emissions in cities. The study identified significant growth in the field, especially after 2006, with the emergence of different carbon accounting methods and the influence of international climate policies. Raza et al (2024) highlighted the underrepresentation of inorganic carbon (SIC) in global soil carbon research, which has largely focused on organic carbon (SOC). Although both groups have similar global carbon stocks, more than 96% of publications and citations pertain to SOC, while SIC research is critical to understanding the carbon cycle and climate change mitigation efforts.

Zheng et al (2022) analyzed 897 publications on carbon accounting in the social sciences from 1997 to 2020, highlighting the need for a comprehensive understanding of research trends and gaps. The research revealed that international trade has generated significant interest in responsibility allocation, with input-output analysis being the most popular method, while emphasizing the need for more focus on organizational emissions and consumer behavior to achieve carbon neutrality. Truant et al (2024) explored the intersection between sustainable supply chain management, carbon accounting, and life cycle assessment (LCA) to develop a structured research agenda. The research synthesized the existing literature, highlighting themes such as the importance of Scope 3 emissions and the integration of LCA into carbon accounting, while discussing the differences in carbon emissions across industries and countries. The research findings suggest that the application of life cycle thinking can improve transparency in the monitoring of carbon emissions in supply chains.

Kurniawan et al (2022) conducted a bibliometric analysis of carbon accounting research from 2012 to 2021, identifying key journals, authors and trends in the field. The research highlighted that 'The Science of the Total Environment' was the most relevant and prolific journal, while the keywords "carbon" and "accounting" dominated the literature. The research shows a growing interest in carbon accounting, with predictions of a continued increase in related publications, particularly on themes such as "emissions" and "study". Du et al (2024) conducted a bibliometric analysis of carbon emissions responsibility accounting, highlighting its importance in addressing global climate change through collaboration between producers and consumers. The study reviewed 4,089 publications, which revealed that China leads in research outcomes, and identified key research focuses and future directions, including city-level accounting and industry chain perspectives.

Hajawiyah et al (2023) reviewed twelve years of carbon accounting research from 2011 to 2022, analyzing 62 articles to identify key themes and future research directions. The research highlights the shift from accounting to carbon emissions accounting, notes the lack of focus on accountability, and suggests that both accounting and auditing standard setters should regulate the recognition and disclosure of carbon emissions. Sheng et al (2025) critically reviewed 1,156 carbon emissions studies using input-output analysis to support carbon neutrality efforts through effective policy formulation. The research highlights the significant increase in research, with China, the US and the UK as major contributors, while identifying gaps in city-level emissions and emerging industries.

This research was conducted to complement existing research and fill the gaps of previous research and to expand the literature related to *Carbon Accounting* through the research path. Specifically, the purpose of this research is to see the development of "*Carbon Accounting*" research published by journals on the theme and see future research opportunities by formulating a research agenda.

METHOD

In this study, various scientific journal publications related to the theme of "*Carbon Accounting*" around the world were used as data sources. Data is collected by searching for journal publications indexed in the Dimension database using the keyword "*Carbon Accounting*". After that, scientific articles or journals that are relevant to the research theme will be selected based on the publication data that has been collected. Journals equipped with DOI are the criteria in the filtering process and data processing using software. There were 18956 journal articles published from within the research theme "*Carbon Accounting*". The development of publication trends related to the research topic was analyzed using VOSviewer software, which can generate bibliometric maps and allow for more detailed analysis.

In order to build the map, VOSviewer uses the abbreviation VOS which refers to Visualizing Similarity. In previous studies, the VOS mapping technique has been used to obtain bibliometric visualizations which are then analyzed. Furthermore, VOSviewer is able to create and display author journal maps based on co-citation data or keyword maps based on co-incidence data (Sukmana et al., 2023; Rusydiana & Rani, 2021). Therefore, this study will analyze journal maps related to "*Carbon Accounting*", including author maps, and keywords which are then analyzed for research paths that can be carried out in the future through clusters in *keyword mapping*.

This research uses a descriptive qualitative approach with meta-analysis and descriptive statistical literature study based on 18956 journal publications that discuss the theme of "*Carbon Accounting*". Meta-analysis is a method that integrates previous research related to a particular topic to evaluate the results of existing studies. Furthermore, the qualitative method used in this research is also referred to as a constructive method, where the data collected in the research process will be constructed into themes that are easier to understand

and meaningful. The sampling technique used in this research is purposive non-probability sampling method, which aims to fulfill certain information in accordance with the desired research objectives.

RESULT AND DISCUSSION

Research Map

The figure below describes the trend of keywords appearing in research on the theme "*Carbon Accounting*" and the larger shapes are the most used words in journal publications on the theme "*Carbon Accounting*".

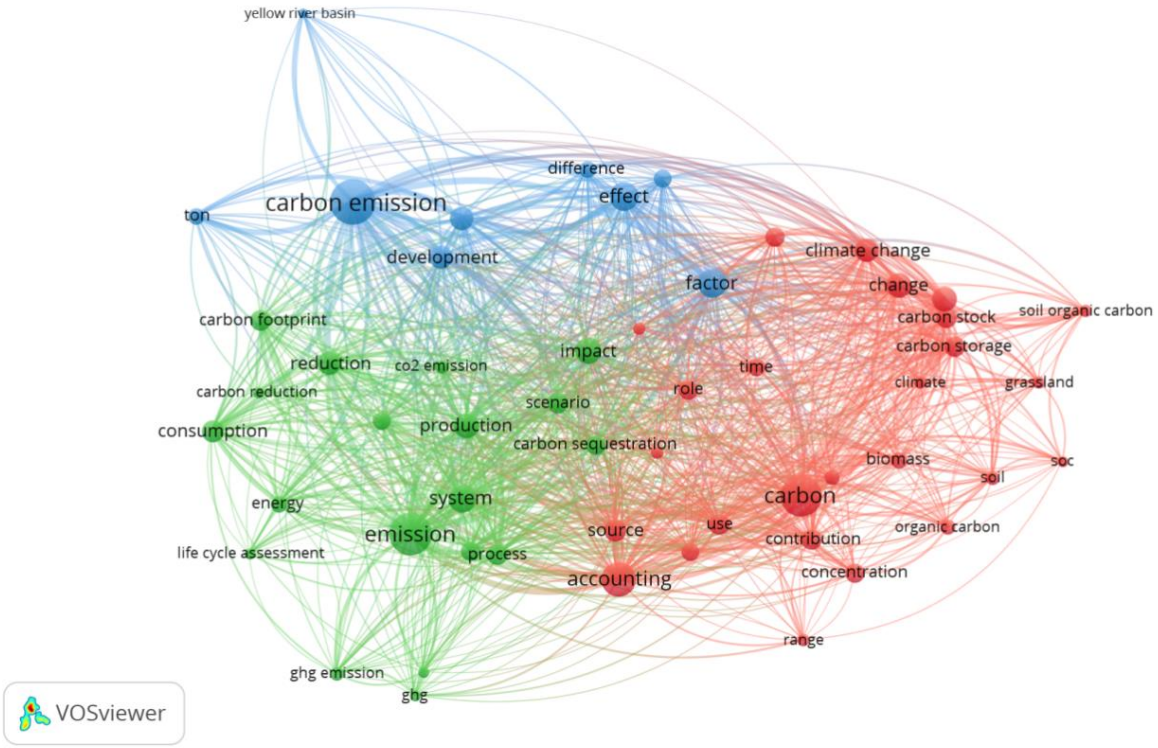

Figure 1. Research Path

As for the mapping, the keywords that appear most in the publication "*Carbon Accounting*" include carbon emission, emission, carbon, production, factor, change, accounting, effect, and consumption, which are then divided into 3 clusters, as follows:

Cluster 1: Carbon accounting in biomass estimation

This cluster contains 26 keyword items, namely accounting, biomass, carbon, carbon accounting, carbon sink, carbon stock, carbon storage, change, climate, climate change, concentration, contribution, estimate, field, forest, grassland, importance, organic carbon, range, role, soc, soil, soil organic carbon, source, time, use. A number of studies relevant to the topics in this cluster include research from Downie et al (2014) describing approaches to greenhouse gas accounting methods for biomass carbon. The study found that the stock method is the most accurate and appropriate approach to use in calculating GHG inventories, but the shortcomings of this approach arise when applied to abatement projects, as it does not account for the increased biogenic CO2 emissions that result when non-CO2 GHG emissions in business-as-usual cases are offset. Therefore, the biogenic method or a modified version of the stock method should be used to accurately estimate the GHG emission reductions achieved by a project.

Baral & Malins (2014) evaluated the carbon impact of bioenergy by analyzing 30 production pathways involving 10 biomass harvesting pathways and three bioenergy production pathways (power generation, biochemical ethanol production, and thermochemical ethanol production). Using a life cycle analysis (LCA) approach, the study considered changes in soil and biomass carbon stocks due to changes in land use, harvesting and cultivation. Criticism of policies such as the EU ETS scheme that assume bioenergy to be carbon-neutral is a concern, as some bioenergy pathways can actually result in higher carbon emissions than fossil fuels. The study also explores the concept of carbon

payback time, carbon intensity over a 30-year period, and the global warming potential (GWPbio) approach to understand the temporary impact of biogenic carbon emissions on global warming.

Preece et al (2015) highlighted the importance of updating national carbon accounting models to consider the contribution of young trees to carbon sequestration. By monitoring the growth of 490 trees of five native species over four years in the Wet Tropics, Australia, the study found that biomass estimates in the first year were much higher than national models, but much lower after four years. Biomass analysis showed that young trees invested more in leaves and branches than trunks, and that species with lower wood density grew faster but had lower survival rates. These results point to the need for adjustments in the national model, including an increase in growth rates after four years before reaching saturation point, to ensure carbon accounting estimates are more accurate.

Paul et al (2006) assessed the uncertainty of carbon accounting models for stemwood density and biomass partitioning of eucalyptus globulus and pinus radiata. This study emphasized the importance of calibrating carbon accounting models in forest systems to be more accurate in carbon trading and offset schemes. The Full Carbon Accounting Model (FullCAM) calculates stem mass based on annual growth volume and base wood density, which is then used to estimate the mass of other tree components. The study developed significant empirical relationships to relate wood density to stand age as well as the distribution of biomass across different tree components. Furthermore, although the prediction of biomass accumulation in foliage and branches was less accurate, its impact on total carbon storage remained small due to stem dominance, especially after more than five years of stand age. Model sensitivity showed that FullCAM could explain 99% of the variance in above-ground biomass, with average carbon estimation uncertainty within 13% of model predictions, thus remaining reliable for carbon accounting purposes in plantation forests.

Other relevant research includes Domke et al (2011) examining accounting for density reduction and structural loss in dead trees through estimates of forest biomass and carbon stocks in the United States. Pulles et al (2022) highlighted the challenges in accounting for greenhouse gas (GHG) emissions associated with the use of biomass as a primary energy source in countries that are parties to the United Nations Framework Convention on Climate Change (UNFCCC). Keith et al (2014) accounted for changes in biomass carbon stocks due to forest fires in temperate landscapes in Australia. Luo et al (2014) analyzed variations in biomass conversion factors in Chinese forests through a study of implications for Biomass and Carbon Accounting. Fraver et al (2013) describe the implications for biomass and carbon accounting of reducing the volume of woody debris due to decay.

Cluster 2: Carbon accounting in emission reduction strategies

This cluster contains 19 keyword items, namely carbon footprint, neutrality, carbon reduction, carbon sequestration, co2, co2 emission, consumption, emission, energy, ghg, ghg emission, greenhouse gas, impact, life cycle assessment, process, production, reduction, scenario, system. A number of relevant studies include Billy et al (2022) proposing a carbon accounting method based on multilevel material flow analysis (MFA) to improve greenhouse gas accounting in industrial plants, specifically using Norwegian aluminum smelters as a case study. The MFA-based approach proved to be more robust than conventional methods, facilitating better performance monitoring, definition of meaningful KPIs, and identification of systemic solutions for emissions reduction while potentially saving costs. Bai et al (2023) analyzed the carbon emissions performance and reduction potential of China's transport sector, estimating a reduction potential of 12.3 million tons, representing 8.4% of annual emissions. The study identified that addressing technology gaps and eliminating management inefficiencies are key contributors to this potential, with specific strategies provided for different provinces to aid low-carbon development.

Yu et al (2024) proposed a comprehensive methodology to calculate the carbon sequestration and emission reduction of the entire livestock and poultry manure utilization chain, emphasizing effective management to achieve carbon neutrality. Using pig farms as a case study. The study evaluated the carbon emission reduction potential and predicted future emission scenarios in China, highlighting the significant reductions achieved through the utilization of manure resources. Gu et al (2023) presented a carbon emission calculation model for iron and steel production, analyzing the relationship between material, energy and carbon flows. The research identifies that combustion emissions are a major contributor to carbon emissions, with significant reduction potential through strategies such as increasing the scrap ratio and using green

electricity, potentially achieving a 65.02% reduction in emissions.

Other relevant research includes Almihoub et al (2013) discussing the development of environmental accounting tools to assist companies in reducing energy use and greenhouse gas (GHG) emissions and improving the accuracy of sustainability information through Activity-Based Costing and Environmental Management Accounting approaches. Martire et al (2018) discussed an extended life cycle-based GHG emissions accounting method to assist local authorities in identifying and implementing emissions reduction actions through waste management, consumption patterns, and land planning and management at the city level. Cardoza Cedillo et al (2023) discussed the carbon footprint (CF) calculation of the Centro Roberto Garza Sada (CRGS) at the Universidad de Monterrey using the GHG Protocol, and proposed a mitigation scenario that could reduce GHG emissions by 63.5% from the baseline.

Kumarasiri & Jubb (2016) described regulatory mixture theory as a framework to investigate the use of management accounting techniques by large Australian listed companies in limiting carbon emissions. Kumarasiri (2017) discussed the relationship between stakeholder pressure, climate change risk management strategies, and management accounting practices in large Australian companies. Imoniana (2018) explored sustainability accounting for Emissions Reduction Credits (ERCs) and compliance with emissions rules through discourse analysis.

Cluster 3: Carbon accounting in Yellow River Basin development

This cluster has 9 keyword items, namely carbon emission, development, difference, effect, factor, increase, region, ton, yellow river basin. Very little research on this topic has been found. Among the relevant studies, Xu & Li (2024) examined the multidimensional ecological compensation mechanism in achieving the "dual-carbon" target in the economic zone of the Yellow River basin, China, by modifying the carbon accounting model to analyze carbon emission and economic data from 59 cities during 2004-2021. The results show that the distribution of ecocompensation credits is more decentralized when inter-regional disparities are taken into account, with uneven low-high and low-low agglomeration patterns and stable ranking of the top five cities in ecocompensation credits each year. The study also found that the level of green technology is a major factor in the spatial and temporal evolution of ecocompensation.

Zhuo et al (2014) addressed sensitivities and uncertainties in water footprint calculations for the production of four major crops of maize, soybean, rice, and wheat in the Yellow River Basin over the period 1996-2005. Using a daily grid-based water balance model, the study analyzed how variations in key input variables, such as rainfall (PR), reference evapotranspiration (ET0), crop coefficient (Kc), and cropping calendar, affected the calculation of green (from rain) and blue (from irrigation) water footprints. The results show that the crop water footprint is more sensitive to ET0 and Kc, with the blue water footprint being more susceptible to input changes than the green water footprint. The uncertainty in the total crop water footprint due to variations in climate inputs was estimated to be around ±20%, while the uncertainty due to the combination of the main input variables reached ±30% at the 95% confidence level.

CONCLUSION

This research aims to find out the extent of the development of research on the theme of "Carbon Accounting" in the world. The results of the study show that the number of research publications related to "Carbon Accounting" there are 18956 journal articles indexed by Dimension. Furthermore, in the development of research related to "Carbon Accounting" based on bibliometric keyword mapping, the most used keywords are emission, emission, carbon, production, factor, change, accounting, effect, and consumption. Based on the keywords that are often used, then grouped into 3 research map clusters with topics that discuss Carbon accounting in biomass estimation, Carbon accounting in emission reduction strategies, and Carbon accounting in Yellow River Basin development.

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