Greenwashing and Corporate Sustainability: A Systematic Literature Review Focusing on AI and Machine Learning Applications

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Abstract

The increase in global interest in sustainable business practices has resulted in a growing demand from stakeholders for companies to report on the environmental and social impacts of their activities. However, some companies have resorted to "greenwashing" providing inaccurate disclosures about their sustainability. This study indicated a gradual increase in research related to greenwashing practices. Many influential studies have occurred since 2007, but a significant growth has been observed in the last 5 years. The geographical dispersion of the work showed that the USA, China, and Europe dominate academic research and that these regions have substantial collaboration with European and Asian researchers.

At the same time, advances in artificial intelligence (AI) have proven to be an important ally for analyzing large volumes of textual information, such as those contained in sustainability reports, quickly and accurately. This article systematically reviews the literature on the use of AI and machine learning (ML) to detect greenwashing in ESG (environmental, social, and corporate governance) reports. Using the PRISMA 2020 statement, articles published in the Scopus database in the last 5 years were analyzed. The bibliometric analysis was conducted considering the interrelationships between greenwashing, sustainability reports, AI, and ML. The findings indicate that despite technological advances, the application of AI and ML in identifying greenwashing is still an emerging field with significant opportunities for future research, highlighting the need for more robust and integrated methods to ensure the accuracy of sustainability disclosures.

Keywords: greenwashing, sustainability reports, artificial intelligence, machine learning, ESG, bibliometric analysis, sustainability

1   INTRODUCTION

Sustainability has emerged as one of the most important concepts in the 21st century, reflecting the need to balance economic development with environmental preservation and social equity. This paradigm guides public policies and corporate strategies, as well as influences consumer behavior and societal expectations (Sachs, 2015). At the heart of this transformation is the sustainability report, an essential tool that allows organizations to communicate their environmental, social, and governance (ESG) performance in a transparent and verifiable manner. These reports are crucial not only for regulatory compliance but also for building trust with stakeholders and making informed decisions that promote sustainable development (Global Reporting Initiative [GRI], 2020).

In the context of corporate sustainability, a concerning phenomenon that has received increasing attention is greenwashing. This term was coined by Jay Westerveld in 1986, criticizing the practice of hotels encouraging their guests to reuse towels under the pretext of protecting the environment, but in reality, only seeking to reduce operational costs (Pearson, 2010). Greenwashing refers to the practice of companies making misleading claims about their environmental efforts to gain competitive advantages or improve their public image without making substantial changes to their operations (Del Maso, Fabrizi, Militello, & Sacchi, 2020). Detecting and mitigating greenwashing is of great importance to ensure the transparency and integrity of sustainability practices.

In this context, and considering recent technological advances, artificial intelligence (AI) and machine learning (ML) have played an increasingly significant role in analyzing large volumes of data, providing detailed analyses that support strategic decisions in both business and society at large (Russell & Norvig, 2020). In the context of sustainability reports, AI and ML can be particularly useful in detecting signs of greenwashing by analyzing patterns and inconsistencies in the data presented (Domingos, 2015). These technologies enable more rigorous and efficient verification of the claims made by companies, contributing to greater transparency and accountability (Marr, 2018).

This article will use bibliometric analysis to examine the intersection between greenwashing, sustainability reports, and the impacts of AI and machine learning. Through this methodology, it will be possible to identify patterns, gaps, and opportunities for future research.

2 THEORETICAL REFERENCES

2.1 Sustainability reports

Sustainability reports represent a fundamental practice in communicating business activities regarding environmental, social, and economic impacts. These reports include a variety of documents, such as corporate social responsibility (CSR) reports, greenhouse gas (GHG) emissions reports, and reports on the UN Sustainable Development Goals (SDGs) (Global Reporting Initiative [GRI], 2021). Academic literature often uses the terms sustainability reports, CSR, and triple bottom line (TBL) reports interchangeably, reflecting the overlap of concepts and practices (Smith, 2020). This practice aims to ensure corporate transparency and accountability to stakeholders, addressing the growing need for sustainable business practices.

Various global organizations have developed standards and guidelines to guide companies in preparing sustainability reports. Entities such as the Global Reporting Initiative (GRI), the International Financial Reporting Standards (IFRS), the European Financial Reporting Advisory Group (EFRAG), and the Sustainability Accounting Standards Board (SASB) have been pioneers in promoting robust standards for ESG (Environmental, Social, and Governance) disclosure (Jones, 2022). Additionally, initiatives by international bodies such as the Task Force on Climate-related Financial Disclosures (TCFD) and the World Economic Forum reinforce the importance of comprehensive and consistent reporting (Deloitte, 2021). The multiplicity of standards and guidelines reflects the complexity and breadth of the concept of sustainability, encompassing various dimensions and interests.

At the core of sustainability reports is the principle of corporate accountability for the impact of their operations. These reports not only provide a detailed view of companies' environmental and social practices but also serve as strategic tools for continuous improvement and the creation of long-term sustainable value (Porter & Kramer, 2019). The adoption of sustainability reporting standards is indispensable for building a more sustainable and resilient global economy, meeting the expectations of investors, consumers, and other stakeholders. Therefore, the development and implementation of sustainability reporting practices promote corporate transparency and the construction of a more sustainable future.

2.2 Greenwashing

Greenwashing, a term derived from the combination of "green" and "whitewashing," refers to the practice of companies promoting their policies or products as environmentally friendly when, in fact, they are not. It is a marketing strategy that seeks to capitalize on the growing consumer demand for sustainable products and services (Bowen & Aragon-Correa,

2014). The concept of greenwashing emerged during the 1980s when environmental activist Jay Westerveld noticed that hotels encouraged guests to reuse towels to "help the environment" while their operational practices were largely unsustainable. This was one of the first documented examples of the discrepancy between environmental claims and actual actions.

As environmental awareness grew in the following decades, greenwashing became a popular strategy among companies looking to attract environmentally conscious consumers without making significant changes to their operations (Delmas & Burbano, 2011). In many cases, these companies invest more in advertising about sustainability than in actual sustainable practices (Laufer, 2003). An iconic example is that of oil companies, which frequently promote their "green" initiatives while continuing to exploit fossil fuels on a large scale. Many argue that such efforts are an attempt to divert attention from the negative environmental impact of their core operations.

Other common forms of greenwashing include the excessive use of nature images on packaging, vague or irrelevant sustainability claims, and the use of uncertified or misleading "green" labels (TerraChoice, 2010). The lack of a clear and standardized definition of what is "green" or "sustainable" often allows companies to benefit from this ambiguity.

2.2.1 Impact of Greenwashing

Greenwashing, the practice of deceiving consumers and investors about the real sustainability of business activities, has profound impacts on the companies involved. First, it undermines corporate responsibility towards stakeholders, eroding the credibility of environmental initiatives. When companies exaggerate or falsify their green credentials, they not only violate the trust placed in them by investors and consumers but also negatively impact their relationships with all stakeholders, including employees, regulators, and local communities. Such a loss of trust can result in severe legal and reputational consequences (Marinho, 2023, p. 12).

The reputational risk associated with greenwashing is significant. Companies involved in greenwashing scandals often suffer damage to their reputation, which can translate into a drop in their stock value. Studies indicate that the negative impact of such scandals can be prolonged, affecting brand perception and customer loyalty in the long term (Silva, 2022, p. 45). A notorious example is the Volkswagen case, which in 2015 was exposed for manipulating emissions tests on its vehicles. This episode not only led to billions in fines and recall costs but also resulted in a sharp decline in the company's market value and a substantial loss of trust among consumers and investors (Jones, 2019, p. 78).

Greenwashing represents a significant threat to ESG (Environmental, Social, and Governance) factors by distorting companies' true environmental performance. Investors seeking alignment with sustainable principles may be misled into making investment decisions based on false information, compromising the integrity of the sustainable investment market (Ferreira, 2020, p. 39). Furthermore, consumers, who increasingly value environmentally responsible products and services, may be deceived, leading to an erosion of trust in the market as a whole and increased skepticism towards companies' sustainability claims (Lima, 2021, p. 22).

Finally, the impact of greenwashing extends to various stakeholders. Investors may face significant financial risks upon discovering that their investment portfolios are not as sustainable as they thought. Consumers may feel betrayed and demotivated to support environmental initiatives, potentially slowing progress towards a more sustainable future. Moreover, the market as a whole may suffer due to widespread distrust, harming companies that genuinely strive for sustainable practices (Souza, 2021, p. 63).

2.2.2 Greenwashing increase and academic productivity

Greenwashing has become an increasingly frequent practice in the corporate world, leading to significant impacts for the companies involved. The rise in greenwashing cases has been confirmed by both regulators and the industry itself, recognizing the expansion of this phenomenon. Deceptive sustainable marketing practices undermine consumer and investor trust, harming the reputation and value of companies in the long term. Additionally, the multiplicity of definitions for greenwashing constitutes a major obstacle to identifying and regulating this behavior. The absence of a clear and uniform definition complicates the creation of precise metrics and the implementation of effective policies to curb such practices (Walker & Wan, 2012).

Academic literature on greenwashing has grown significantly in recent years, reflecting increasing concern with the transparency and veracity of corporate sustainability practices. Authors such as Lyon and Montgomery (2015) and Delmas and Burbano (2011) have substantially contributed to the understanding of this phenomenon, exploring the motivations and consequences of greenwashing. Between 2016 and 2020, there was a notable increase in the number of publications on the topic, driven by growing awareness of the importance of environmental responsibility and consumer pressure for greater transparency.

The period from 2020 to 2023 saw an even sharper rise in publications on greenwashing, with studies delving deeper into methodologies for detecting and analyzing this practice. Literature reviews highlight the complexity and multifaceted nature of greenwashing and suggest practical approaches for its identification and mitigation. This growth in the literature is crucial for providing a solid knowledge base that can guide both regulators and companies in promoting genuinely sustainable practices (Lyon & Montgomery, 2015).

Furthermore, recent academic reviews emphasize the need for standardization of definitions and methodologies for evaluating greenwashing. The diversity of theoretical and empirical approaches, while enriching, can also lead to divergent conclusions, complicating the formulation of efficient public policies. It is vital for future studies to continue exploring ways to harmonize these definitions and criteria, promoting a more cohesive and operational understanding of greenwashing (Delmas & Burbano, 2011).

2.3 Artificial Intelligence and Machine Learning

AI presents multiple opportunities and possibilities to change society, whether in the production of goods or services, in business in general, or in the formation and change of approaches to environmental and social issues (De La Vega Hernández, Urdaneta, & Carayannis, 2022; Hopkins, 2022). The field is becoming increasingly relevant both in terms of its impacts and the transformations of various sectors (De La Vega Hernández, Urdaneta, & Carayannis, 2022; Feuerriegel et al., 2022). In the context of sustainability, AI can have positive and negative impacts on social, economic, and environmental outcomes, reflecting its importance in relation to the field of sustainability and, concomitantly, to sustainability reporting (Vinuesa et al., 2020).

A subfield of AI that has emerged is machine learning (ML). ML uses algorithms to recognize patterns, make decisions, and mimic how humans learn and solve problems (Macpherson, Gasperini, & Bosco, 2022; Goodell et al., 2021; Feuerriegel et al., 2022). ML, like AI, has become increasingly prominent in academic literature, reflected by the increase in the occurrence of the term, as well as its evolution to sometimes be seen as distinct or autonomous from AI in academic literature (De La Vega Hernández, Urdaneta, & Carayannis, 2022).

Natural language processing (NLP), itself a subset of AI and ML, uses algorithms and ML to analyze texts, enabling the analysis of large amounts of data much faster than manual analysis and review (Jan Van Eck & Waltman, 2021). Recent bibliometric studies identify NLP

as an emerging topic that requires more research in the future (De La Vega Hernández, Urdaneta, & Carayannis, 2022), while academic tools, such as VosViewer, employ NLP to conduct bibliometric analyses (Jan Van Eck & Waltman, 2021).

Text mining is related to NLP as "it is the process of transforming unstructured text into structured data for easy analysis," and "it uses natural language processing tools to interpret human language and automatically process text documents" (Civitani, 2021).

3 METHODS AND MATERIALS

This study is based on the literature reviews of Freitas Netto et al. (2020) and Yang et al. (2020), which broadly address the concepts and consequences of greenwashing. Freitas Netto et al. analyzed 263 publications, retaining 42 articles that met the review criteria between 2009 and 2018, following the PRISMA guidelines. The results indicate that greenwashing, the practice of disseminating positive information about a company's environmental performance while concealing negative aspects, is multifaceted and can undermine consumer trust. Yang et al. reviewed 67 articles published between 2000 and 2020, highlighting that multinationals in emerging markets tend to practice greenwashing due to weak implementation of environmental regulations. Both studies suggest the need to strengthen regulations to mitigate the negative effects of greenwashing.

To build the base of articles for this study, the PRISMA 2020 Statement, a set of rigorous guidelines aimed at increasing the transparency and quality of systematic reviews and meta-analyses, was adopted. PRISMA 2020 consists of a 27-item checklist and a four-phase flow diagram, covering everything from study identification to inclusion in the review, minimizing biases and increasing the reproducibility of studies. The application of PRISMA is also advantageous in bibliometric analyses, allowing a detailed quantitative assessment of scientific production. The 2020 updates improved the flexibility and applicability of PRISMA in various fields of knowledge, including social and human sciences, reflecting recent technological and methodological changes.

Additionally, a bibliometric analysis was conducted to complement the application of PRISMA 2020. This quantitative approach allowed the identification of publication patterns, leading authors, prominent journals, and other relevant information on greenwashing. The analyses included productivity by author, country, field of knowledge, funding source, type of publication, keyword analysis, total citations, and publication time series. The main database used was Scopus, which covers more than 20,000 peer-reviewed journals. Search criteria were used to obtain articles on sustainability reports, artificial intelligence, machine learning, and greenwashing, forming a solid basis for understanding the current state of knowledge and gaps in the literature.

4 DISCUSSION

4.1 Prisma 2020

PRISMA 2020 methodology conducted in the Scopus database resulted in an initial total of 123 articles relevant to the topic of interest. During the screening process, 2 duplicate articles

were identified and excluded, and 4 articles were excluded for not specifically addressing the phenomenon of greenwashing. Additionally, 1 article was eliminated for not addressing the topics of artificial intelligence, machine learning, or sustainability. In the end, 116 articles were deemed suitable for subsequent bibliometric analysis.
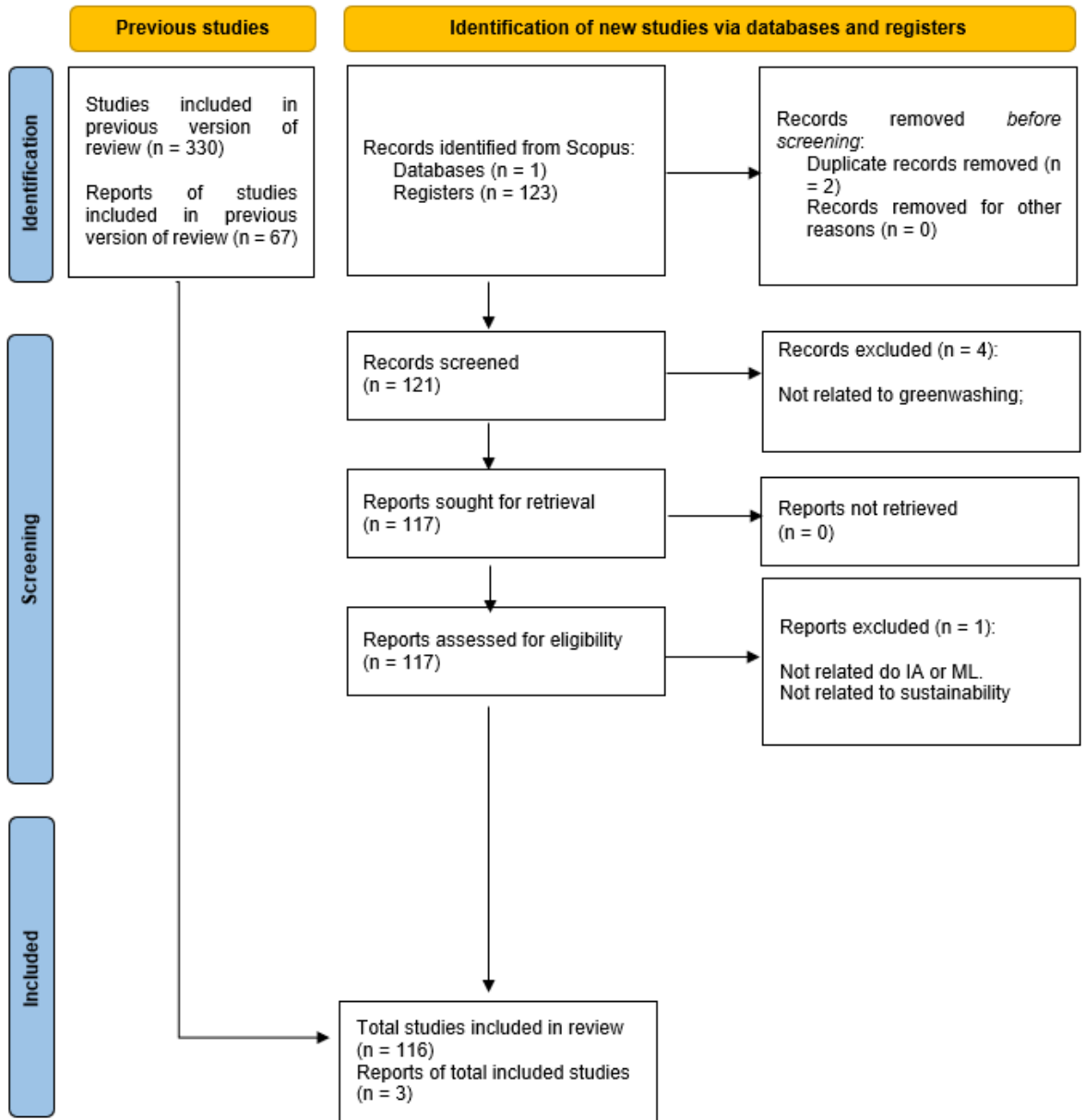

Figure 1 – PRISMA 2020 methodology results

4.2 Bibliometric analysis - Results

As presented in section 4.1, we identified 123 published documents and narrowed them down to 116 articles using the PRISMA 2020 Statement. The publications span the period from 2019 to 2023, with an average growth rate of 1.175%. The following figure presents the temporal series of the publication of the analyzed documents:
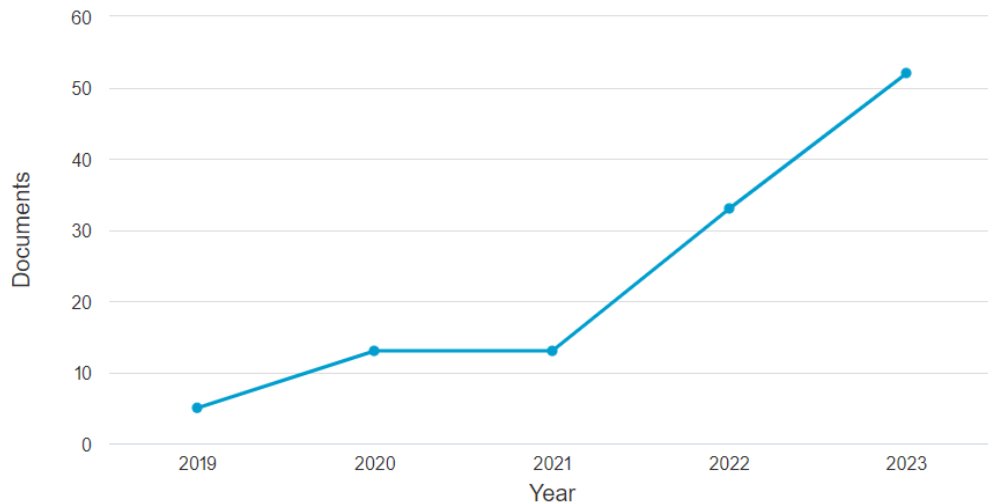

Figure 2 – Publication Time-Series

The temporal evolution of scientific production on the topics of greenwashing, artificial intelligence (AI), machine learning, and sustainability showed a significant increase in the number of published documents between 2019 and 2023. In 2019, only 5 documents were published, while in 2020 there was a slight increase to 13 publications.

Production remained stable in 2021 with 13 documents, but from 2022 an exponential growth was observed, with 33 publications. This growth intensified further in 2023, reaching 52 documents. This substantial increase over the years indicates greater awareness and urgency regarding greenwashing and sustainability issues, reflecting the growing importance and relevance of these areas on the global stage.

Additionally, the increase in document production suggests advances in research and an expansion of scientific discussions and discoveries, promoting continuous enrichment of the existing body of knowledge. Regarding the distribution of documents by type, most are articles, representing 73.3% of the total, with 85 publications. Conference papers follow, constituting 19.8% of the scientific production, totaling 23 documents.

Reviews represent 6.9% of the total, with 8 documents. This distribution shows a significant predominance of articles in scientific journals, indicating a robust and in-depth academic focus on the studied topic. The considerable number of conference papers suggests an active and ongoing debate in academic forums and specialized events.

The presence of recent reviews, although smaller, highlights the importance of consolidating and critically evaluating existing knowledge in the area. Together, these data reflect a scenario of diversified scientific production, with a balance between the dissemination of new findings and the review of the state of the art in the field of finance and sustainability.
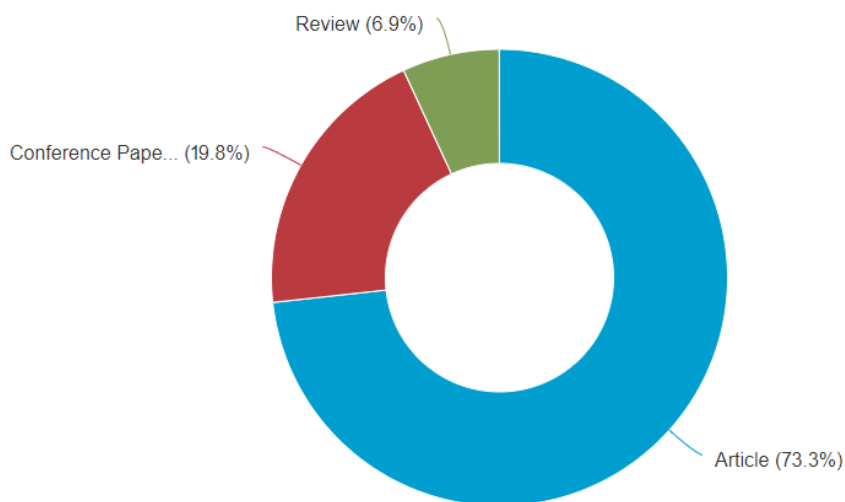
Figure 3 – Documents by type of publication

Considering the scientific productivity on the topic by country or territory, it is evident that the United States leads with the highest number of publications, totaling 16 documents. China, Germany, and India follow as the main contributors, with 12 documents each. Spain and Italy also present a significant number of publications, with 10 and 8 documents, respectively. Countries like Australia, the United Kingdom, the Netherlands, and Portugal, although not at the top of the ranking, demonstrate relevant participation, ranging from 6 to 4 documents.

It is important to highlight that, since 2019, China has been increasing the number of published articles on the topic, reinforcing the interest of this developing nation in scientific progress in the field of finance and sustainability.

This distribution evidence the predominance of developed countries in the scientific production of the addressed topic, reflecting advanced infrastructure and investments in research and development in these locations. Additionally, the geographic diversity of the contributing countries suggests a global dissemination of interest in the topic, which can enrich the academic debate with varied and intercultural perspectives.
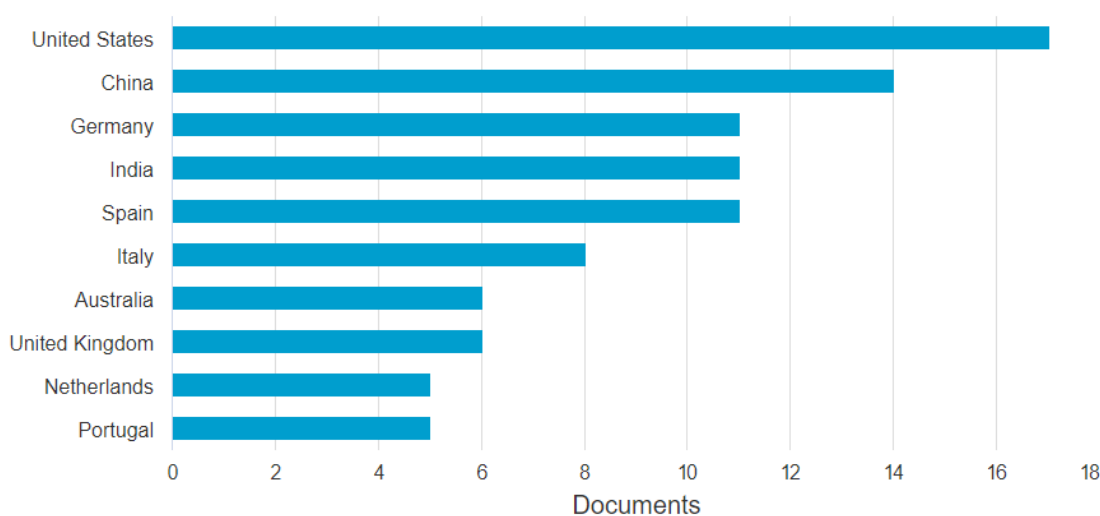

Figure 4 - Scientific productivity by country or territory

The distribution of documents by area of knowledge, focusing on the themes of greenwashing, artificial intelligence (AI), machine learning, and sustainability, indicates that most documents are concentrated in the areas of Business, Management, and Accounting, with 49 publications, representing 17.4% of the total. Social Sciences follow with 41 documents (14.5%), and Environmental Sciences with 39 documents (13.8%). Computer Science also has a significant representation, with 37 documents (13.1%), highlighting the importance of AI and machine learning technologies in sustainability research.

Economics, Econometrics, and Finance, along with Energy, contribute 31 documents each (11.0%), underscoring the critical intersection between finance, energy policies, and sustainable practices. Decision Sciences, with 22 documents (7.8%), and Engineering, with 18 documents (6.4%), show the practical applicability and strategic analysis involved in these studies. Other areas, including Mathematics and Humanities, have a smaller but relevant contribution to an interdisciplinary perspective.
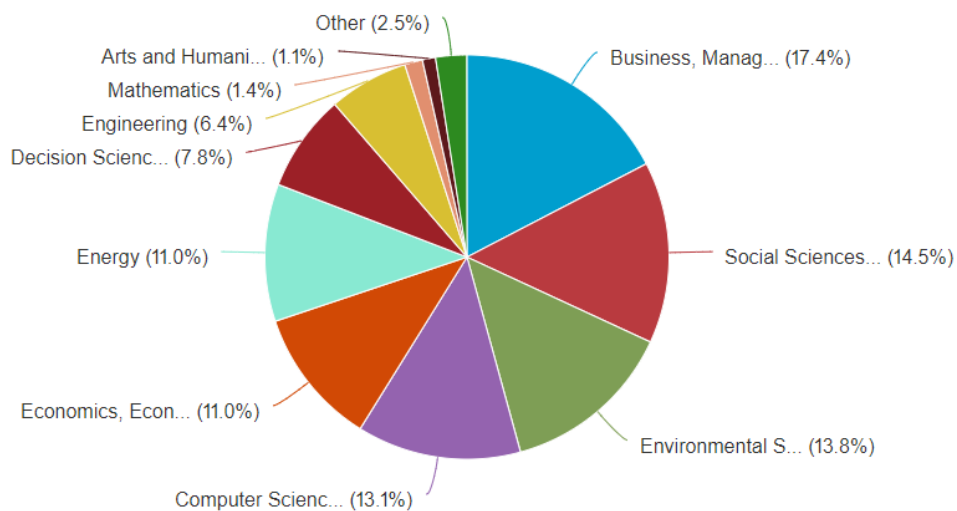

Figure 5 - Distribution by area of knowledge

The distribution of documents by funding sources illustrates the main sources of funding for research on greenwashing, artificial intelligence (AI), machine learning, and sustainability. The European Commission leads with four funded documents, indicating its prominent role in supporting globally relevant research in these areas. The National Office for Philosophy and Social Sciences of China follows with three documents, reflecting the country's growing interest in scientific development and sustainability issues. Several other institutions, including the Basic and Applied Basic Research Foundation of Guangdong Province, the Foundation for Science and Technology, and European programs such as Horizon 2020 and Horizon 2020 Framework Programme, each contributed two documents.

The diversity of the authors' countries of origin indicates a wide range of interests and methodological approaches, reflecting the interdisciplinary and global nature of the research. This collaborative scenario is important for advancing knowledge, allowing the integration of different perspectives and expertise to address the complex challenges associated with these topics. Furthermore, the presence of several authors with similar contributions may indicate a well-established research network, promoting the exchange of ideas and the development of innovative and sustainable solutions.
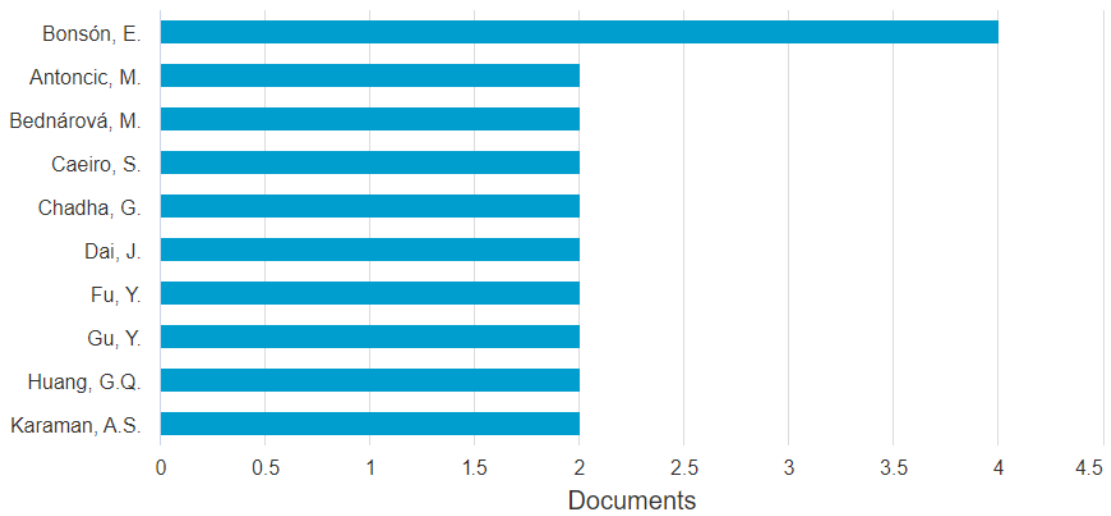
Figure 6 – Distribution by author

The distribution of documents by journal, highlighting the main sources of research publication, indicates that the journal "Sustainability (Switzerland)" leads by a significant margin, accounting for 16 documents. This is followed by several journals with 3 publications each, including "Corporate Social Responsibility and Environmental Management," "International Journal of Accounting Information Systems," "Journal of Cleaner Production," and "Sustainability Accounting Management and Policy Journal."

Journals such as "Australasian Accounting Business and Finance Journal," "Business Strategy and the Environment," "Cogent Business and Management," "Corporate Communications," and "Electronics (Switzerland)" each have 2 publications.

This distribution evidences the centrality of the journal "Sustainability (Switzerland)" in disseminating relevant research on the topic, while the diverse presence of other journals indicates a broad and interdisciplinary interest in the study.

The variety of journals also suggests that research in this area is being widely discussed in different academic and practical contexts, promoting a continuous enrichment of the debate and the dissemination of innovative knowledge.
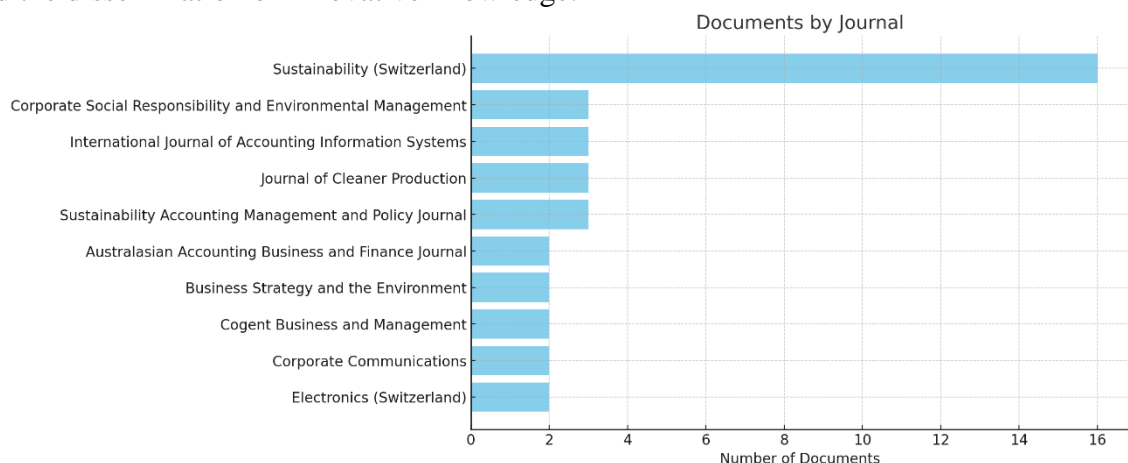

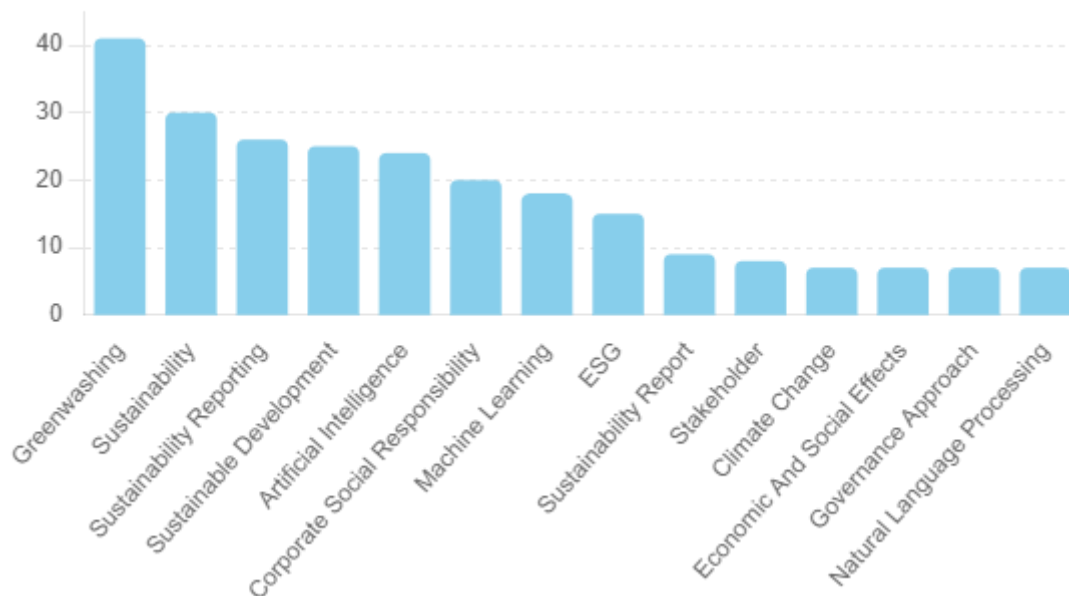Figure 7 – Distribution by periodical

Figure 8 – Keywords distribution

Of the 116 documents analyzed, the keyword "Greenwashing" leads with 41 documents, reflecting a growing concern about deceptive practices in corporate sustainability claims. "Sustainability" follows with 30 documents, indicating the broad relevance of the concept in the current context. Terms such as "Sustainability Reporting" (26 documents) and "Sustainable Development" (25 documents) demonstrate a robust focus on the communication and implementation of sustainable practices.

"Artificial Intelligence" appears in 24 documents, underscoring the importance of emerging technologies in the analysis and promotion of sustainability. "Corporate Social Responsibility" with 20 documents and "Machine Learning" with 18 documents highlight the role of corporate responsibilities and advanced data analysis techniques in this field.

Other relevant topics include "ESG" (15 documents), "Sustainability Report" (9 documents), "Stakeholder" (8 documents), "Climate Change" (7 documents), "Economic And Social Effects" (7 documents), "Governance Approach" (7 documents), and "Natural Language Processing" (7 documents), which together highlight the complexity and interconnectedness of the issues studied.

Finally, the table presented below offers a comprehensive view of the 20 most cited articles involving the themes of greenwashing, machine learning, artificial intelligence (AI), and sustainability. These articles highlight the main scientific contributions and the areas of greatest interest and impact within this field of study.

The most cited article, "Greenwashing in environmental social and governance disclosures" by Yu et al. (2020), with 286 citations, highlights the critical concern of the academic and professional community regarding the veracity of environmental, social, and governance (ESG) disclosures. This high number of citations reflects the relevance and urgency of understanding and combating greenwashing practices.

Another notable article is "Past present and future of sustainable finance: insights from big data analytics through machine learning of scholarly research" by Kumar et al. (2022), which received 147 citations. This work emphasizes the importance of using big data and machine learning in analyzing financial sustainability, showing how emerging technologies are revolutionizing the field. Articles such as "Is corporate social responsibility reporting a tool of signaling or greenwashing? Evidence from the worldwide logistics sector" by Uyar et al. (2020), with 122 citations, and "Green brand of companies and greenwashing under sustainable

development goals" by Pimonenko et al. (2020), with 98 citations, also highlight concerns about the authenticity of corporate social responsibility and sustainability practices. These studies are fundamental to understanding the dynamics of signaling versus deceptive practices in corporate disclosures.

The diversity of topics covered in the cited articles, including frameworks for assessing the ESG impacts of AI, the real effects of CSR reporting in the European Union, and the intersections between greenwashing and the circular economy, reflect the complexity and interconnectedness of the issues at play. This citation analysis not only illuminates the areas of greatest impact and relevance in the field but also points to a continuous need for rigorous and multidisciplinary investigations to address the challenges and opportunities in sustainability and technology.

4.3 Greenwashing, sustainability reporting and the application of AI and machine learning

Despite the increase in the number of published articles on the topic of greenwashing since 2022, this trend is not reflected in research on greenwashing and AI or machine learning. This becomes evident when analyzing various maturity metrics, such as the number of documents addressing the intersection of these two fields, as well as the average age and duration of the documents within the analyzed corpus.

Both of the intersections reveal a significantly more developed body of research in terms of maturity, including the average age of the documents and the period covered. Notably, the corpus addressing the intersection of AI and machine learning with sustainability reports is the most extensive and advanced among all the intersections analyzed.

Clear trends were identified in keywords associated with central themes such as sustainability and sustainable development. Significant trends are also observed related to the high frequency of keywords linked to AI and machine learning tools and techniques, such as data mining, text mining, big data, and artificial intelligence. However, these trends do not reflect that AI and machine learning can be effectively applied to the theme of greenwashing.

Nevertheless, the importance of applying AI and machine learning in the domain of sustainability reports is corroborated by the thematic analysis, which identifies a degree of maturity in the use of these techniques in this field. The broad application of AI and machine learning tools, such as natural language processing, in sustainability reports, reflects an initial perception of the utility of these technologies by researchers.

Finally, a mature or widespread application of AI and machine learning techniques in the other intersections is not observed, leading to the inference that the use of AI and machine learning concerning greenwashing, as well as greenwashing in sustainability reports, is still a relatively unexplored field of research.

This conclusion is particularly relevant, considering the negative impacts of greenwashing on sustainability and sustainable communication, and the potential that AI and machine learning have to mitigate these impacts.

5   CONCLUSIONS

This systematic literature review highlighted the growing concern with the phenomenon of greenwashing and the importance of using advanced artificial intelligence (AI) and machine learning (ML) techniques to detect it. The increase in academic production on greenwashing in recent years reflects a growing awareness of the need to ensure transparency in corporate sustainability practices. The bibliometric analysis showed that despite the considerable volume of research, the application of AI and ML in detecting greenwashing is still in its early stages.

Additionally, the review revealed that most research on greenwashing is concentrated in specific regions, such as the United States, China, and Europe, indicating a need for more comprehensive studies that include diverse geographic regions and cultural contexts. The geographic concentration of research may limit the global understanding of the phenomenon and its manifestation in different markets and regulations.

Another point identified is the inherent complexity in detecting greenwashing. Although AI and ML tools can be important instruments for indicating possible signs of greenwashing through the analysis of sustainability reports, they are not the only means and should be complemented by other approaches. The lack of an established standard for sustainability report disclosure and the absence of specialized auditing institutions exacerbate this challenge. Without standards, analysis becomes more challenging and lacks parameters, often resorting to techniques such as sentiment analysis, which, while useful, are not decisive in judging whether a company has committed greenwashing.

Thus, the problem of greenwashing may be more of a regulatory issue, involving the definition of clear communication standards and the accountability of companies that practice greenwashing.

Finally, the review indicates that there is a great space for future research exploring the integration of AI and ML in the evaluation of sustainability reports, developing more robust methodologies to identify and prevent greenwashing practices. Collaboration between academics, technology professionals, and regulators will be essential to advance in this area and ensure that corporate sustainability practices truly align with sustainable development goals.

5.1 Research limitations

This study presents some limitations that should be acknowledged. Firstly, the analysis was restricted to articles available in the Scopus database, which may have excluded relevant publications present in other databases, such as Web of Science and ScienceDirect. This may have led to a partial view of the current state of research. Additionally, focusing on articles published in the last five years may have overlooked fundamental studies conducted in earlier periods, which could provide relevant insights into the evolution of the greenwashing phenomenon and technological approaches for its detection.

Although the analysis focused on publications in English, which is justifiable given that most related articles are produced in this language, other limitations include the possible exclusion of relevant studies from other fields of knowledge that could have contributed to a more comprehensive understanding of the topic. Interdisciplinarity is important to capture all nuances of greenwashing and its detection, and this limitation may have affected the completeness of the findings.

5.2 Contributions

This work offers several important contributions to the literature on corporate sustainability and greenwashing. Firstly, it provides a comprehensive overview of the current state of research on the application of AI and ML in detecting greenwashing, identifying trends, gaps, and future opportunities. The bibliometric analysis conducted provides a quantitative perspective on the interrelationships between greenwashing, sustainability reporting, and emerging technologies, highlighting the key authors, journals, and institutions contributing to this field of study.

Additionally, the study serves as a valuable guide for academics and professionals seeking to understand and address greenwashing more effectively. The recommendations for

future research and methodological development proposed in the work provide a clear roadmap for improving the accuracy and transparency of corporate sustainability disclosures. By highlighting the need for more integrated and robust approaches, the study contributes to the advancement of research and practice in the field of sustainability.

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