ARTIFICIAL INTELLIGENCE AND ESG: TRENDS, GAPS, AND OPPORTUNITIES IN BIBLIOMETRIC ANALYSIS

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ABSTRACT

This study presents a comprehensive bibliometric analysis of scholarly literature at the intersection of Artificial Intelligence (AI) and Environmental, Social, and Governance (ESG) practices. Using data from the Scopus database (2015–2025) and analyzed through VOSviewer 1.6.20, a total of 885 relevant documents were mapped to identify major trends, gaps, and opportunities within this emerging research field. The analysis reveals a significant growth in publications from 2022 onward, with a peak in 2024, reflecting the increasing relevance of AI-driven solutions for ESG implementation, reporting, and decision-making. Key findings highlight the dominance of themes such as technological innovation, machine learning in finance, and sustainability metrics. Three main thematic clusters were identified: digital infrastructure and ESG reporting systems; bibliometric and conceptual studies; and AI applications in investment and financial performance. Despite the promising integration of AI to enhance ESG outcomes, the study also uncovers gaps related to ethical concerns, regulatory frameworks, and underrepresentation in developing countries. This research contributes to a deeper understanding of the evolving knowledge landscape and offers strategic insights for academics, practitioners, and policymakers aiming to harness AI for sustainable and responsible governance.

Keywords: Artificial Intelligence, ESG, Bibliometric Analysis

INTRODUCTION

In recent years, the concept of Environmental, Social, and Governance (ESG) has emerged as a crucial benchmark for corporate sustainability and responsible governance. As global attention to sustainability issues continues to grow, there is an increasing demand for accurate, transparent, and efficient ESG reporting. Amid the complexity of such reporting, Artificial Intelligence (AI) has emerged as a potential solution to help companies respond more adaptively to external dynamics and regulatory pressures (Li et al., 2025; Yu et al., 2025). The rapid advancement of AI has brought transformative impacts across various sectors, including within the ESG

domain. AI facilitates the automation of reporting processes, real-time data collection and validation, and large-scale data analysis to detect sustainability patterns that are difficult to identify through conventional approaches (KPMG, 2024b). This technology also presents significant opportunities to accelerate emissions tracking, strengthen internal control systems, and enhance transparency and accountability across value chains (FII Institute, 2024; Yu et al., 2025).

The concept of Environmental, Social, and Governance (ESG) has evolved into a strategic framework that plays a crucial role in defining corporate responsibility and sustainability amid the growing challenges of climate change and rising social expectations. ESG principles demand not only compliance with environmental and social standards but also promote ethical and transparent governance as an essential aspect of corporate accountability (Câmara & Morais, 2022; Read, 2023). In a global context, ESG serves as a transformative tool for business models, encompassing risk management, green market opportunities, and long-term stakeholder engagement (E. Popkova & Sergi, 2023). Effective ESG practices rely on a systematic framework, including the integration of measurable metrics and evaluation indicators (MSCI, 2024). Furthermore, implementing ESG requires a practical operational approach, from employee engagement to the selection of responsible supply chain partners (Dathe et al., 2024). Increasingly, market players are recognizing that long-term economic success depends significantly on a company's ability to internalize ESG principles into its core strategies (The Global Compact, 2004). ESG is now understood not merely as a reporting tool but as a strategic instrument for creating shared value for both business and society (Dathe et al., 2024).

The surge in generative AI usage has drastically increased energy consumption, prompting investors to consider the environmental and regulatory impacts especially in regions with limited renewable energy infrastructure (ClimeCo, 2024). Increasingly stringent regulations are pushing companies to align with TCFD, ISSB, and IFRS standards in order to enhance capital appeal through strong ESG scores, enable cross-sector and cross-country benchmarking, and position ESG as a source of innovation and long-term resilience rather than mere compliance. ESG assets are projected to exceed USD 53 trillion by 2025 more than a third of total global assets and could surpass USD 40 trillion by 2030 (Bloomberg, 2025). In Indonesia, the adoption of Artificial Intelligence (AI) has been proven to significantly enhance corporate ESG performance, which in turn increases firm value although gaps remain in terms of technical capacity, regulatory frameworks, and policy standards amid growing stakeholder pressure and the push for formally documented digital and sustainability policies (Mulyana et al., 2025).

However, the integration of AI into ESG frameworks also introduces critical challenges. Concerns around algorithmic bias, the lack of transparency in machine-driven decision-making, and potential ethical violations underscore the importance of adopting Responsible AI principles that align with ESG values (Csiro, 2024). Therefore, a deeper understanding of the intersection between AI and ESG is becoming increasingly essential. Previous studies have shown that AI can enhance operational efficiency and support corporate digital transformation, ultimately contributing to improved ESG performance (Ahmad et al., 2023; Musleh Al-Sartawi et al., 2022). Nevertheless, the existing literature remains fragmented and has yet to provide a comprehensive overview of the scientific developments in this field. Many thematic, methodological, and contextual aspects of AI-ESG integration remain underexplored (Kumar et al., 2024). To address this gap, bibliometric analysis serves as a relevant approach. By mapping the scientific literature, this method can identify key actors, research trends, cross-country collaborations, and the evolution of knowledge at the intersection of AI and ESG. Furthermore, bibliometric analysis can reveal research gaps that can serve as the foundation for future research agendas (Huang et al., 2023; Zhang & Yang, 2024).

Bibliometric analysis also holds strategic value in supporting evidence-based decision-making for academics, practitioners, and policymakers alike(Ismail et al., 2012). Amid rapid technological development and escalating sustainability demands, it is vital for all stakeholders to gain a comprehensive understanding of the evolving knowledge landscape that underpins the integration of AI into ESG practices. Against this background, the present study aims to provide a holistic mapping of the relationship between AI and ESG using a bibliometric approach. This research not only seeks to uncover dominant trends and patterns in the scholarly literature but also offers practical recommendations for companies, research institutions, and regulators in promoting strategic, ethical, and sustainable AI integration. Ultimately, the findings of this study are expected to contribute meaningfully to shaping the direction of future research and to assist companies in navigating both the challenges and opportunities associated with leveraging AI to achieve ESG objectives more effectively and responsibly. Introduction contains the background of the problem, a review of previous literature as a basis for stating the article's novelty, research problems or hypotheses and research objectives.

METHOD

This study adopts a quantitative approach using bibliometric analysis to identify and map research trends related to Artificial Intelligence (AI) and

Environmental, Social, and Governance (ESG), specifically focusing on trends, gaps, and opportunities. Bibliometric analysis employs various mathematical and statistical methods to evaluate bibliometric data (Donthu et al., 2021). The aim of this analysis is to uncover the dynamics of the topic, key contributing authors or institutions, and dominant themes in scholarly publications (Hoang, 2025; Passas, 2024). Bibliometric data were obtained from the Scopus database due to its broad and credible coverage of international scientific journals. The data retrieval, measurement, and analysis processes were conducted through the Scopus website (https://www.scopus.com). The data collection involved the use of specific search keywords with the following query syntax: TITLE-ABS-KEY (("artificial intelligence" OR "AI" OR "machine learning" OR "algorithmic decision making" OR "data-driven") AND ("environmental social governance" OR "ESG" OR "sustainability reporting" OR "corporate sustainability" OR "ESG performance" OR "sustainable finance")).

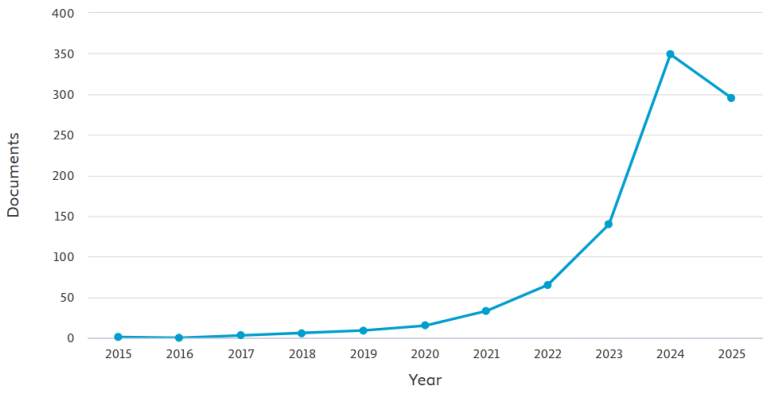
A total of 916 documents were identified for the period 2015–2025. After filtering, the relevant document types consisted of Articles (510), Conference Papers (195), Book Chapters (132), and Reviews (48), amounting to 885 documents in total. Other document types such as Books, Editorials, Conference Reviews, Notes, Errata, Short Surveys, and Data Papers were excluded from the results. The study was conducted in three main stages. The first stage involved defining the scope of the research, during which the researchers established the topic and analytical coverage by selecting relevant keywords and ensuring an adequate number of documents (≥2000) to validate the analysis. The selected option is "Title and abstract fields", meaning that terms will be extracted from both the titles and abstracts of the documents. The second stage focused on data collection, where bibliometric data were extracted from the Scopus database in RIS format using the selected keywords. The third stage involved data analysis, including performance analysis to assess publication and citation productivity, science mapping to explore relationships among keywords and other attributes, and network analysis using VOSviewer to visualize thematic linkages and identify major clusters within the analyzed literature. The data was processed using VOSviewer 1.6.20.

RESULTS AND DISCUSSION

Bibliometric Data

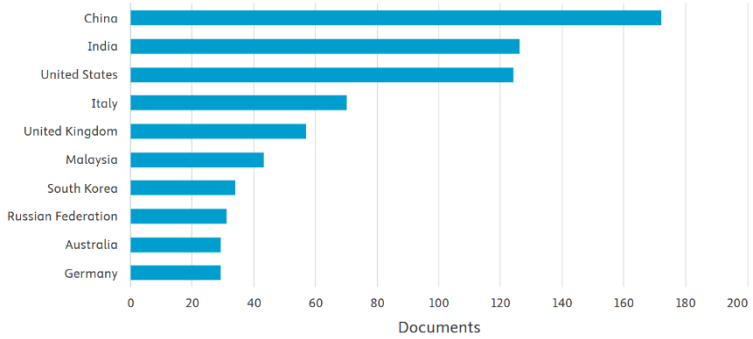
The research trend on Artificial Intelligence and Environmental, Social, and Governance (ESG) from 2015 to 2025 shows a significant year-over-year increase. The peak of publications occurred in 2024, with a total of 349 documents. Prior to that, the annual number of publications was very low and relatively stagnant, especially before

2020. A sharp rise began in 2022, marking growing academic interest in the integration of AI into sustainability issues. This trend reflects the increasing urgency and relevance of interdisciplinary studies combining intelligent technologies with sustainable practices in both global and local contexts.



Gambar 1. Document by years (Source: Scopus 2015-2025)

The increase in the number of publications in 2024 aligns with the findings of the KPMG 2024 ESG Organization Survey, which revealed that 56% of organizations plan to enhance ESG data colection with the help of AI, and 49% view improved ESG data management and reporting through AI as a key factor in integrating ESG goals into business strategy (KPMG, 2024)



Gambar 2. Document by country (Source: Scopus 2015-2025)

Based on the document by country graph, the distribution of scientific publications related to artificial intelligence and ESG shows that China is the largest contributor, with the highest number of publications, followed by India and the United States, both of which also recorded significant figures. Next in line are Italy, the United Kingdom, and Malaysia, indicating strong interest and active engagement in this topic. Countries such as South Korea, Russia, Australia, and Germany also contributed,

although with fewer publications. This pattern reflects the dominance of countries with strong research capacities, as well as the growing global attention to the integration of intelligent technologies into sustainability and environmental-social governance agendas. In Indonesia, scientific publications in this field remain very limited, with only 12 articles identified. This indicates a significant untapped research potential, particularly related to the country's unique local context and challenges. For example, research on CEO career variety influencing the level of ESG disclosure highlights the importance of governance quality in improving sustainability reporting in Indonesia (Rahmatulloh et al., 2025).

Table 1. The Most Cited Articles on Artificial Intelligence and ESG

Titles	Authors & Years	Total Citation	Result
Fintech and sustainability: Do they affect each other?	(Vergara & Agudo, 2021)	211	Artificial Intelligence, when integrated into Fintech platforms, significantly enhances the assessment and monitoring of Environmental, Social, and Governance (ESG) criteria by enabling real-time data processing, detecting greenwashing practices, and providing investors with more accurate, transparent, and actionable sustainability insights."
FinBERT: A Large Language Model for Extracting Information from Financial Text	(Huang et al., 2023)	205	FinBERT significantly improves the accuracy and efficiency of extracting sentiment and financial information from text, outperforming traditional methods in financial natural language processing task
Past, present, and future of sustainable finance: insights from big data analytics through machine	(Kumar et al., 2024)	187	This study provides a comprehensive, data-driven review of sustainable finance research, mapping its key themes, contributors, and methods, while offering future directions that

Titles	Authors & Years	Total Citation	Result
learning of scholarly research			integrate emerging technologies like AI and blockchain
Sustainability of the Metaverse: A Transition to Industry 5.0	(Emerson et al., 2012; Sætra, 2021)	141	This study finds that artificial intelligence significantly enhances corporate sustainability by improving environmental efficiency, promoting circular economy practices, and facilitating ESG reporting and decision-making
Does good ESG lead to better financial performances by firms? Machine learning and logistic regression models of public enterprises in Europe	(De Lucia et al., 2020)	136	By applying machine learning models, this study demonstrates that artificial intelligence can effectively predict financial performance from ESG indicators, highlighting the strategic value of integrating AI into sustainability analysis
Financing sustainable entrepreneurship: ESG measurement, valuation, and performance	(Mansouri & Momtaz, 2022)	118	This study reveals that the integration of machine learning and natural language processing enhances ESG risk assessment by extracting material signals from unstructured text data, thereby improving the predictive accuracy of financial risk models
A framework for evaluating and disclosing the esg related impacts of ai with the sdgs	(Emerson et al., 2012)	109	This study develops a framework using the UN Sustainable Development Goals (SDGs) to systematically evaluate and disclose the ESG related impacts of artificial intelligence, addressing

Titles	Authors & Years	Total Citation	Result
			current gaps in sustainability reporting practices
Artificial intelligence (AI)-enhanced medical drones in the healthcare supply chain (HSC) for sustainability development: A case study	(Damoah et al., 2021)	106	This study demonstrates that AI enhanced medical drones significantly improve healthcare supply chains in developing countries by reducing mortality rates, lowering carbon emissions, and advancing multiple UN Sustainable Development Goals (SDGs
Recent advancements and challenges in emerging applications of biochar-based catalysts	(Yuan et al., 2023)	105	Artificial intelligence, particularly through natural language processing and machine learning techniques, significantly enhances the accuracy and efficiency of ESG scoring by analyzing unstructured textual data from corporate disclosures
The effect of green energy, global environmental indexes, and stock markets in predicting oil price crashes: Evidence from explainable machine learning	(Ben Jabeur et al., 2021)	100	Advanced machine learning models, especially XGBoost and LightGBM, effectively predict crude oil price crashes during the COVID-19 pandemic, with green energy and ESG indicators playing a significant role in the forecasting process

Source: Scopus, 2025

The top 15 most-cited articles on Artificial Intelligence (AI) and ESG reveal a growing convergence between emerging technologies and sustainability imperatives.

These studies highlight how AI particularly through machine learning, natural language processing, and explainable models like FinBERT, XGBoost, and LightGBM enhances ESG risk assessment, sustainability reporting, and financial forecasting. Applications span sectors such as fintech, healthcare, energy, and even the Metaverse, demonstrating AI's cross-cutting impact. Several works also integrate the UN Sustainable Development Goals (SDGs) to frame ESG-related AI evaluations. Despite these advances, notable gaps persist in the form of limited empirical coverage across regions, underdeveloped ethical frameworks, and lack of standardized ESG metrics. These gaps present key opportunities for future research to explore inclusive, transparent, and globally adaptable AI applications in sustainability governance.

Table 2. The Most highly co-occurring keywords.

Term	Cluster Number	Link	Total Link Strength	Occurrences
Technology	1	338	2930	243
Machine	2	333	3133	191
Firm	4	312	1744	150
Effect	4	317	1630	148
Investor	2	305	1751	145
Integration	1	313	1613	127
Algorithm	2	313	1502	125
Solution	1	295	1256	105
Enterprise	4	271	1093	93
Prediction	2	272	1095	91
Accuracy	2	283	1123	91
Indicator	2	275	1007	89

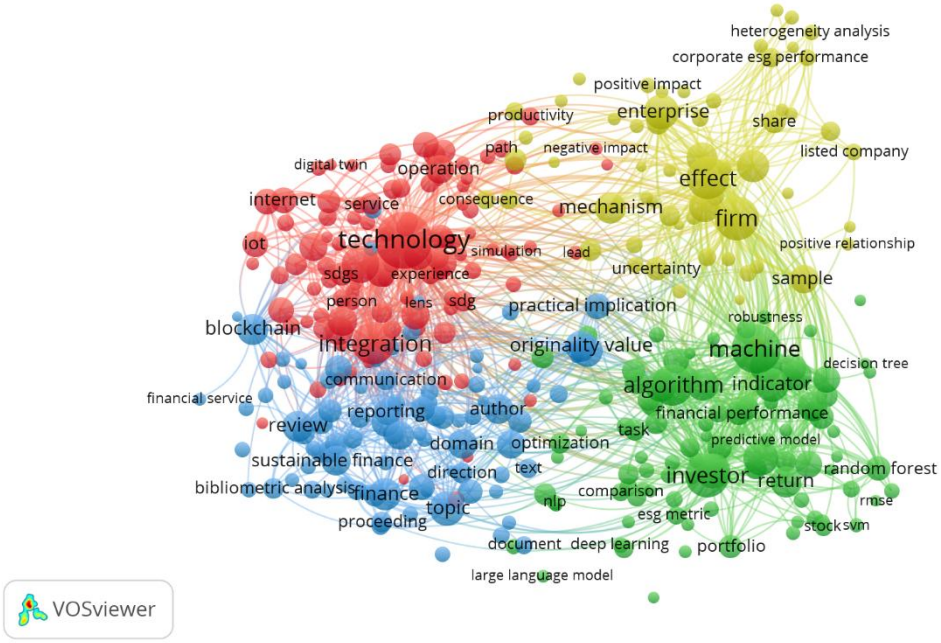
Term	Cluster Number	Link	Total Link Strength	Occurrences
ESG Peformance	4	266	983	88
Topic	3	279	1070	83
Score	2	243	816	80

Source: Processed using VOSviewer, 2025

Based on the VOSviewer analysis of Scopus data on the topic Artificial Intelligence and ESG: Trends, Gaps, and Opportunities in Bibliometric Analysis, the most frequently occurring keyword is "Technology", which appears 243 times and has the highest total link strength of 2,930 across 338 connections. This indicates that "Technology" serves as a central and highly integrated term within the research network, reflecting its foundational role in linking Artificial Intelligence applications to Environmental, Social, and Governance (ESG) issues. Other prominent keywords include "Machine," "Firm," and "Effect," suggesting significant attention toward machine-based systems, organizational contexts, and the impacts of AI in ESG-related studies. This suggests that bibliometric studies in this field are heavily centered on technological innovation and machine-based methodologies, highlighting a strong emphasis on how advancements in artificial intelligence are being integrated into corporate, environmental, and governance frameworks.

Bibliometric Mapping and Geographical distribution

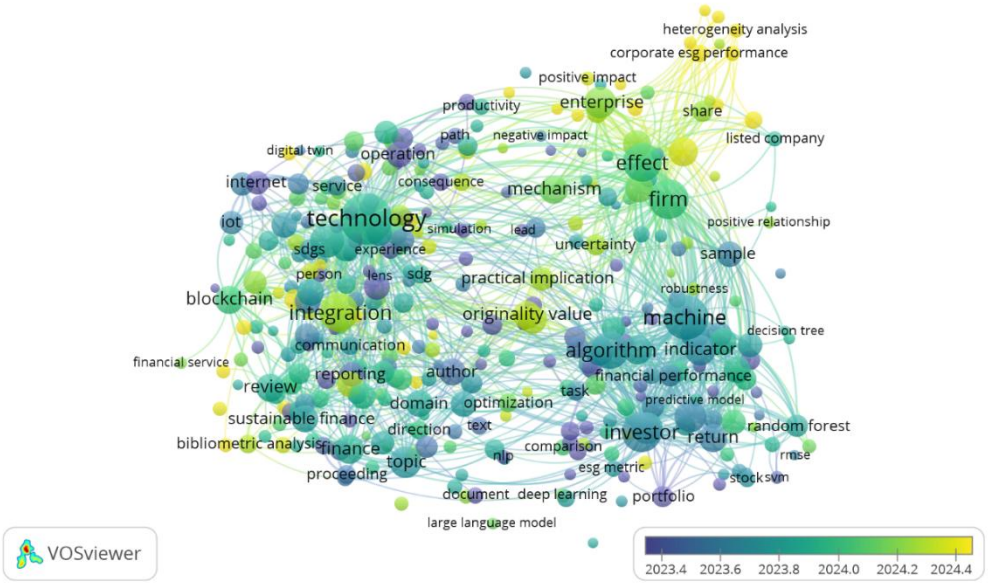
The analysis is divided into two parts: co-occurrence mapping and co-authorship mapping. Co-occurrence, also referred to as a semantic network, refers to the relationships between keywords, while co-authorship pertains to interactions among authors, contributing countries, or affiliations in the development of a particular field or research area. In the co-occurrence mapping, all keywords are treated as units of analysis, using the full counting method. The researchers set a minimum occurrence threshold of 10 times for a term; out of a total of 20,642 identified terms, 558 met the specified criteria. Next, from the 558 terms that met the threshold, a relevance score will be calculated for each term. Based on this score, the most relevant terms will be selected; by default, the system will choose 60% of the most relevant terms to be visualized in the mapping.



Gambar 2. Network Visualization (Source**:** Processed using VOSviewer, 2025)

Based on the bibliometric analysis using VOSviewer, three main clusters were identified, each representing thematic focuses within the literature on Artificial Intelligence (AI) and ESG. The first cluster (marked in red) centers on the theme of technological infrastructure and digital transformation, with dominant keywords such as technology, operation, internet, iot, digital twin, and service. This indicates a strong scholarly emphasis on how emerging technologies like the Internet of Things (IoT), blockchain, and simulation tools are being leveraged to support sustainable development goals (SDGs) and integrate ESG considerations into operational systems. The presence of terms such as SDGs, integration, and reporting in this cluster also reflects the growing effort to align digital transformation with sustainability reporting frameworks and ESG transparency.

The blue cluster focuses on bibliometric mapping, research evaluation, and the conceptual development of AI-ESG intersections. Keywords such as sustainable finance, review, reporting, finance, and bibliometric analysis indicate that this cluster is driven by meta-level academic work, including literature reviews and mapping studies that aim to assess the intellectual structure and evolution of this field. This cluster highlights the role of researchers in synthesizing knowledge, identifying gaps, and proposing future research directions. Meanwhile, the green cluster reveals a concentration on machine learning applications in finance and investment, with keywords like machine, algorithm, investor, prediction, financial performance, and random forest. This signifies a practical and data-driven approach, focusing on how AI models can be applied to enhance ESG scoring, investment returns, and decision-making in corporate and financial contexts. This result relate to Artificial Intelligence (AI) can be leveraged to scale ESG by extracting data-driven insights, automating ESG processes and reporting, utilizing third-party data for product-level emissions profiles, managing and verifying supplier emissions across diverse datasets, and ensuring compliance across regulatory boundaries (KPMG, 2024)



Gambar 2. Geographical distribution (Source**:** Processed using VOSviewer, 2025)

The overlay visualization from VOSviewer illustrates the temporal evolution of keyword co-occurrences in the literature on Artificial Intelligence (AI) and ESG, using a color gradient from dark blue (older, around early 2023) to yellow (more recent, early 2024). Central keywords such as "technology," "integration," and

"algorithm" appear in shades of green, indicating that they have remained consistently relevant across the analyzed period. These terms form a dense, interconnected core that suggests the sustained importance of technological integration and computational methods in ESG-related research. Keywords like "blockchain," "iot," and "deep learning" are clustered near the core and represent the enduring role of foundational digital technologies in the ongoing discourse.

Notably, terms in yellow, such as "corporate ESG performance," "heterogeneity analysis," and "positive impact", suggest emerging interests and recent publications. These newer keywords point to a growing focus on evaluating real-world implications of AI-driven ESG initiatives, particularly at the corporate level. Additionally, the appearance of terms like "listed company," "share," and "robustness" indicates a shift toward quantitative assessment and financial modeling of ESG strategies. The visualization overall reflects a field in transition—from a foundational emphasis on digital infrastructure and methodological frameworks to a more applied and evaluative phase, where researchers are beginning to assess outcomes, measure impact, and refine ESG metrics through advanced AI tools.

CONCLUSION

This study concludes that the intersection of Artificial Intelligence (AI) and Environmental, Social, and Governance (ESG) is a rapidly evolving research area characterized by increasing scholarly interest, particularly in the application of digital technologies to support sustainable governance and corporate accountability. While current research highlights the strategic potential of AI in enhancing ESG performance, it also reveals critical challenges related to ethical risks, algorithmic transparency, and the lack of contextualized frameworks for implementation especially in emerging economies. To move forward, future research should adopt interdisciplinary approaches that integrate technological innovation with normative ESG values, promote region-specific case studies, and strengthen global collaboration to develop inclusive, transparent, and adaptable AI-ESG solutions. Stakeholders particularly companies, regulators, and academic institutions are encouraged to leverage bibliometric insights to design evidence-based strategies that align AI development with long-term sustainability goals and responsible governance.

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