

# Digital ESG Analytics: A Bibliometric Review of AI-Driven Sustainability Research (2010–2025)

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## Abstract

This study provides a comprehensive bibliometric mapping of Digital ESG Analytics by synthesizing evidence from 643 peer-reviewed publications published between 2010 and 2025. Using data extracted from Google Scholar and Scopus and analyzed with VOSviewer, the study demonstrates a sharp rise in research output beginning in 2023, reflecting growing global demand for transparent, technology-enabled ESG assessment. The keyword co-occurrence analysis maps eight major thematic clusters—ranging from ESG reporting, AI-driven analytics, technological innovation, machine learning models, and sustainability goals to sector-specific ESG applications—illustrating how the field has shifted from descriptive ESG discussions toward predictive, automated, and data-intensive approaches. Overlay visualization further highlights the temporal evolution of research, with recent years dominated by themes such as NLP-based sentiment analysis, generative AI, real-time analytics, and digital ESG integration. Co-author network examination indicates fragmented global collaboration, with a small number of regional clusters—particularly from East Asia—forming the primary collaborative nodes. Building on these findings, the study outlines three major research gaps: (1) conceptual limitations such as the lack of integrated theoretical frameworks; (2) methodological constraints, including limited high-quality datasets and insufficient use of advanced analytical techniques; and (3) contextual and sectoral gaps involving under-representation of SMEs, emerging markets, and resource-constrained environments. Correspondingly, the study proposes future research directions that encourage theoretical consolidation, methodological strengthening, greater transparency and explainability in AI-enabled ESG models, and broader exploration of sectoral and geographical contexts. Overall, the study enhances understanding of the structure, evolution, and research frontiers of Digital ESG Analytics, offering valuable insights for scholars, practitioners, and policymakers seeking to advance data-driven sustainability governance.

**Keywords:** Digital ESG Analytics, Artificial Intelligence, Sustainability Reporting, Machine Learning, ESG Performance, Big Data Analytics

## 1. Introduction

In the last decade, Environmental, Social, and Governance (ESG) considerations have become central to corporate strategy, investor decision-making, and regulatory agendas worldwide. Recent systematic and bibliometric reviews show a sharp rise in ESG-related publications, driven by mandatory disclosure requirements, stakeholder pressure, and the integration of sustainability metrics into financial performance evaluation (Gafni et al., 2024; Khamisu & Paluri, 2024; Tiong et al., 2025). At the same time, sustainability reporting has evolved from voluntary narratives to a multidimensional information system that links ESG disclosure with circular economy practices and integrated reporting, reflecting a broader shift toward green and responsible economic models (Krasteva-Hristova et al., 2025).

Parallel to this evolution, advances in digital technologies—particularly Artificial Intelligence (AI), Machine Learning (ML), and big data analytics—have begun to transform how ESG information is generated, processed, and used in financial and managerial decisions. Lim (2024) highlights that AI applications now permeate ESG trading strategies, ESG scoring, risk management, and forecasting, creating a new research frontier at the intersection of sustainable finance and data science. Complementing this, Elhady and Shohieb (2025) show how AI-driven tools support ESG metrics, climate-risk modeling, and global implementation of sustainable finance, while Ekaristi et al (2025) document the growing use of big data and AI techniques to enhance the measurement and transparency of ESG performance. A lot positive impacts of mandatory ESG disclosure on firm transparency, stakeholder scrutiny, and financial performance, underpinning the acceleration in ESG-related research and reporting (Moharram et al., 2024)

Despite the rapid expansion of research on ESG and digital technologies, the knowledge base remains fragmented across disciplines, methodologies, and data sources. Existing reviews tend to focus on isolated components—such as ESG reporting, integrated reporting, AI applications in sustainable finance, or big-data-driven ESG measurement—without offering a unified perspective on how digital technologies collectively reshape ESG analytics and bibliometric studies have typically focused either on overall ESG performance literature (Tiong et al., 2025), sustainability reporting and integrated reporting (Krasteva-Hristova et al., 2025), or on the broader intersection of AI, ESG, and sustainable finance as a niche within financial innovation (Davidescu et al., 2025). Likewise, Ekaristi et al. (2025) show that big data and AI in ESG performance measurement still constitute an emerging and relatively underdeveloped research area, with a limited but fast-growing body of work.

These fragmented insights indicate a clear need for a focused mapping of what can be termed Digital ESG Analytics: the use of AI, ML, and data-driven technologies to support ESG measurement, reporting, and decision-making in business and finance. Recent state-of-the-art reviews call for more structured understanding of AI–ESG interactions, including issues of data quality, model transparency, ethical risks, and the impact of digital tools on sustainable value creation (Khamisu & Paluri, 2024; Lim, 2024). In parallel, empirical and conceptual work in sustainable digital finance emphasizes that AI-driven ESG systems offer significant opportunities but also face maturity, governance, and implementation challenges, particularly in emerging markets (Ekaristi et al., 2025; Elhady & Shohieb, 2025). Against this backdrop, a comprehensive bibliometric analysis is essential to consolidate dispersed knowledge, inform dominant themes and collaboration patterns, and identify research gaps that will shape the future of Digital ESG Analytics

However, despite the rapid growth of ESG, AI, and sustainability analytics research, existing studies remain highly fragmented and do not provide a consolidated understanding of how digital technologies jointly shape ESG measurement and reporting. Previous bibliometric studies have examined isolated components of the field—such as ESG performance and disclosure trends (Tiong et al., 2025), sustainability reporting architectures (Krasteva-Hristova et al., 2025), or AI in sustainable finance (Davidescu et al., 2025)—but none has systematically mapped the integrated domain now emerging as Digital ESG Analytics. Moreover, recent reviews highlight persistent gaps related to the lack of unified frameworks, low comparability across ESG datasets, inconsistent methodological approaches, and limited cross-disciplinary synthesis between data science, sustainability accounting, and financial technology (Lim, 2024;

Moharram et al., 2024). These limitations indicate that the existing literature has not yet provided a holistic overview of publication trends, thematic clusters, collaboration patterns, and intellectual foundations that define this rapidly evolving field.

This study addresses these gaps by offering one of the first comprehensive bibliometric analyses that integrates ESG, AI, machine learning, digital reporting, and sustainable finance into a unified research landscape. By analyzing 643 peer-reviewed publications from Scopus and Google Scholar using VOSviewer software, this study provides a novel, data-driven mapping of Digital ESG Analytics—identifying dominant research clusters, co-authorship structures, co-citation networks, and emerging research fronts that have not been synthesized in previous literature. Unlike earlier reviews focusing on only one element of the domain, this study contributes a broader interdisciplinary perspective and highlights how digital technologies reshape ESG transparency, climate-risk modeling, and corporate sustainability strategies. The findings offer theoretical contributions to sustainability science, practical insights for ESG practitioners and regulators, and methodological advances for future research on technology-enabled sustainability reporting.

The rapid expansion of research on the intersection between ESG practices, digital technologies, and AI-driven analytics has created a growing need to systematically map the intellectual structure and thematic evolution of this emerging field. Several recent studies indicate that Digital ESG Analytics—defined as the application of AI, machine learning, natural language processing, and big data techniques to ESG measurement and reporting—has become a critical enabler for corporate sustainability strategies, investment decision-making, and regulatory compliance (Elhady & Shohieb, 2025; Lim, 2024). However, existing studies remain fragmented and limited in scope, often focusing on specific ESG themes or isolated analytical techniques (Davidescu et al., 2025; Tiong et al., 2025).

Given these gaps, the aim of this study is to provide a comprehensive bibliometric analysis of the global literature on Digital ESG Analytics using VOSviewer. By analyzing 643 peer-reviewed publications from Scopus and Google Scholar, this study seeks to examine major research clusters, understand collaboration networks, and notify the intellectual foundations that drive this rapidly evolving domain. Such a synthesis is essential for guiding future research, enhancing methodological alignment, and supporting both practitioners and policymakers in the design of AI-enabled ESG frameworks (Ekaristi et al., 2025; Khamisu & Paluri, 2024).

Accordingly, the main objectives of this study are:

1. To examine global publication trends in Digital ESG Analytics from 2010 to 2025.
2. To analyze authorship level collaboration networks.
3. To identify major research themes and clusters through keyword co-occurrence mapping
4. To highlight emerging themes, research gaps, and future directions for Digital ESG Analytics.

Based on these objectives, the study addresses the following Research Questions (RQs):

1. RQ1: How has scientific production related to Digital ESG Analytics evolved over the past decade?
2. RQ2: What major thematic clusters characterize the current research landscape?
3. RQ3: Which authors form the core collaboration networks in Digital ESG Analytics research?

4. RQ4: What research fronts and thematic developments can be identified from keyword and cluster-based bibliometric mapping?
5. RQ5: What gaps and opportunities for future research can be identified from the bibliometric evidence?

## 2. Literature Review

### 2.1 ESG Concepts and Evolution

Environmental, Social, and Governance (ESG) represents a multidimensional framework used to evaluate corporate sustainability performance through environmental stewardship, social responsibility, and governance practices. ESG initially emerged as an extension of socially responsible investment (SRI) but has since evolved into a globally recognized assessment system adopted by investors, regulators, and corporations (Friede et al., 2015; The Principles for Responsible Investment (PRI), 2023). Over the past decade, regulatory bodies such as the European Commission and global standard setters like the International Sustainability Standards Board (ISSB) have strengthened mandatory disclosure requirements, accelerating the integration of ESG into corporate reporting and financial decision-making (ISSB, 2023; World Economic Forum, 2024). This institutional shift reflects the growing consensus that ESG performance contributes to long-term value creation, resilience, and risk mitigation.

The evolution of ESG has also been marked by the move from narrative, voluntary disclosures toward standardized and data-driven sustainability reporting. Recent studies highlight how global frameworks—such as the Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), and ISSB—have shaped the convergence of ESG metrics and improved comparability across industries (Khan et al., 2016; Krasteva-Hristova et al., 2025). Moreover, the expansion of green finance and sustainable investment instruments has intensified the need for reliable ESG data, prompting organizations to leverage digital technologies to enhance accuracy, transparency, and assurance of ESG disclosures (Elhady & Shohieb, 2025; Lim, 2024). As a result, ESG today is not only a reporting obligation but a strategic pillar in global business transformation, influencing corporate governance, capital allocation, and long-term competitiveness.

### 2.2 Digital Analytics

Digital analytics refers to the systematic use of data collection, processing, and computational techniques to extract insights and support decision-making across business, finance, and sustainability domains. The proliferation of big data, cloud computing, and advanced data engineering has enabled organizations to analyse large, complex datasets at unprecedented scale and speed (Provost & Fawcett, 2013; Sutriana, 2023). According to Huynh et al. (2023) big data analytics capabilities have evolved into a strategic asset that enables firms to process diverse and high-volume datasets to enhance value creation, improve operational efficiency, and support evidence-based decisions. In the sustainability context, digital analytics plays a crucial role in extracting structured and unstructured ESG-related information from corporate disclosures, news feeds, social media, and real-time operational systems. Tools such as natural language processing (NLP), text mining, and sentiment analysis enhance ESG transparency and support risk assessment within emerging digital sustainability frameworks (Ekaristi et al., 2025; Lim, 2024).

The evolution of digital analytics has also been shaped by the growing need for reliable sustainability information in capital markets and regulatory ecosystems. With increasing

pressure for standardized ESG disclosure, digital analytics has become central to automated data assurance, credibility assessment, and fraud detection in sustainability reporting (Elhady & Shohieb, 2025). Meanwhile, advancements in dashboarding, visualization, and data pipelines and decision makers to integrate financial, environmental, and social indicators into unified analytic frameworks. These developments position digital analytics as a critical foundation for AI-driven sustainability systems, enabling more accurate measurement, predictive modeling, and continuous improvement of ESG practices

### *2.3 AI-Driven Sustainability*

Artificial Intelligence (AI) has become a transformative force in accelerating sustainability and climate-risk analytics. Where it is done with by enabling the processing of high-frequency, high-volume environmental and financial data that traditional analytical approaches cannot manage effectively. Recent studies show that machine learning, deep learning, and advanced pattern-recognition techniques significantly enhance the accuracy of air and water quality monitoring, pollution detection, and the forecasting of extreme weather events and environmental hazards (Ayoola et al., 2024). Through the integration of AI with sensor networks and the Internet of Things (IoT), organizations and policymakers are able to conduct real-time ecological monitoring, uncover emerging hotspots, and design timely interventions that support climate adaptation strategies and environmental resilience. These technological developments demonstrate how AI is reshaping environmental management and enabling a shift toward proactive ecosystem governance (Olawade et al., 2024).

In the corporate and financial sectors, AI-driven analytics are increasingly applied to evaluate Environmental, Social, and Governance (ESG) indicators, predict sustainability performance, and assess embedded climate-risk exposures within investment portfolios. A comprehensive synthesis by Lim (2024) shows that AI applications in ESG and sustainable finance cluster across domains such as investment and trading, ESG measurement and disclosure, risk management, and responsible AI governance. Empirical studies further indicate that AI adoption positively influences corporate ESG performance through enhanced information efficiency, innovation, and green productivity (Chen et al., 2024). AI-enabled platforms also support automated sustainability assurance, anomaly detection, and greenwashing identification, contributing to greater transparency and trust in corporate sustainability claims. As regulatory and market expectations expand, the convergence of AI capabilities with ESG demands has given rise to a new domain known as digital ESG analytics, where sustainability and climate risks are quantified, monitored, and integrated directly into strategic business and investment decision-making.

### *2.4 Digital ESG Analytics*

Digital ESG Analytics refers to the integration of data analytics, machine learning, natural language processing (NLP), and automated evaluation systems to measure, monitor, and enhance Environmental, Social, and Governance (ESG) performance. This domain has emerged in response to the rapid expansion of ESG disclosures and the increasing demand for transparent, high-quality sustainability data among regulators, investors, and corporations. According to Lim (2024) AI-based ESG analytics have become central to investment decision-making, climate-risk evaluation, and automated interpretation of corporate sustainability disclosures, especially through NLP-driven text analysis and ESG scoring models. Likewise, Elhady and Shohieb (2025) emphasize that digital ESG systems integrate big data pipelines

with AI algorithms to enhance sustainability reporting accuracy, captures anomalies, and reduce subjectivity in traditional ESG assessment processes. These advancements highlight a structural shift toward data-rich, technology-enabled ESG evaluation frameworks that are more consistent, scalable, and responsive to real-time environmental and social signals.

The evolution of Digital ESG Analytics is also shaped by the convergence of financial innovation, sustainable investment, and advanced computational methods. Recent studies demonstrate that AI-enabled ESG analytics improve corporate accountability by detecting greenwashing patterns, assessing supply chain risks, and linking sustainability outcomes with long-term firm value (Chen et al., 2024; Davidescu et al., 2025). Furthermore, bibliometric evidence suggests that Digital ESG Analytics is becoming a distinct interdisciplinary field that integrates sustainability science, information systems, financial economics, and machine learning (Ekaristi et al., 2025). As global regulatory bodies such as the ISSB and ESMA increase reporting requirements, digital ESG analytics is expected to play a pivotal role in enhancing the comparability of ESG disclosures, strengthening market integrity, and supporting climate-aligned decision-making across industries. Overall, the emergence of Digital ESG Analytics sets the foundation for a deeper exploration of research trends, thematic clusters, and intellectual structures—making bibliometric analysis an essential tool for mapping this rapidly evolving landscape.

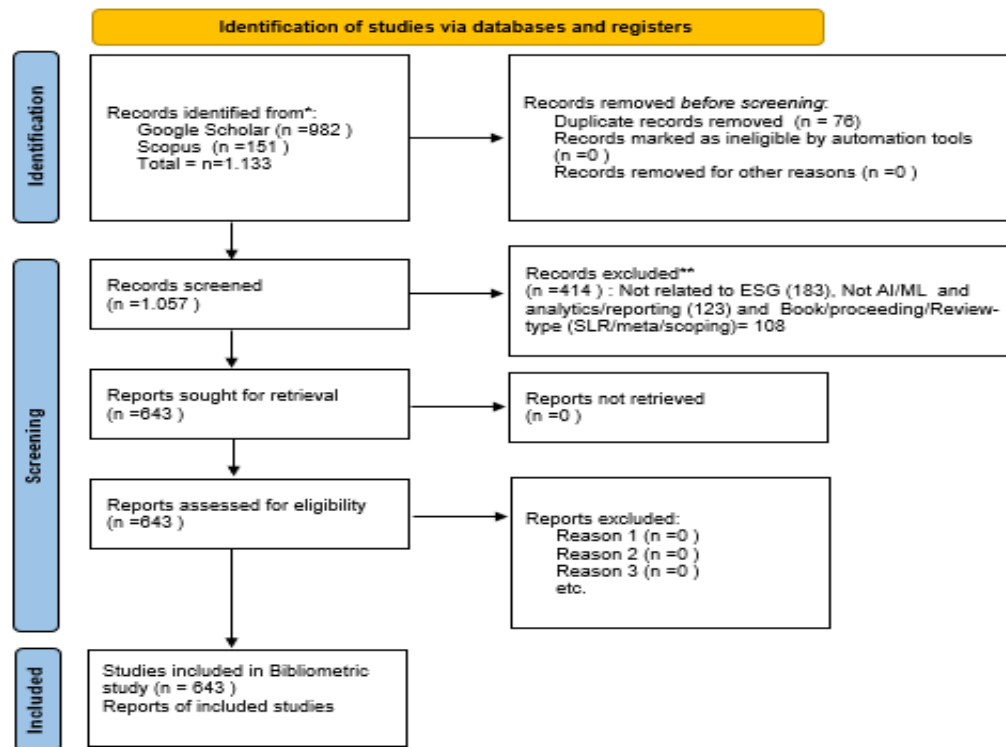
### 3. Research Method

#### 3.1 Data Source and PRISMA Procedure

A comprehensive search was conducted using Google Scholar and Scopus databases to mapping publications related to Digital ESG Analytics, Artificial Intelligence, and Sustainability Reporting. The search yielded a total of 1,133 records, comprising 982 records from Google Scholar and 151 records from Scopus.

After the removal of duplicates ( $n = 76$ ), a total of 1,057 unique records were retained for title and abstract screening. During this stage, 414 records were excluded for the following reasons: not related to ESG ( $n = 183$ ), not relevant to AI/ML or analytics/reporting ( $n = 123$ ), and publications outside the intended scope such as book chapters, conference proceedings, reviews, SLRs, bibliometric studies, scoping reviews, and meta-analyses ( $n = 108$ ).

This left 643 records for eligibility assessment. Because this study is a bibliometric review and all included records were accessible, no full-text exclusions occurred ( $n = 0$ ). Thus, a total of 643 studies were included in the final bibliometric analysis. The detailed selection process follows the PRISMA 2020 Flow Diagram as shown in Figure 1 (Page et al., 2021) below:



Source: Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

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**Figure 1 . PRISMA Diagram  
(Source: Author analysis)**

### 3.2 Data Analytic with VOSViewer

The bibliometric data extracted from 643 eligible publications were analyzed using VOSviewer version 1.6.20, a widely adopted tool for visualizing scientific landscapes through network-based mapping (Van Eck & Waltman, 2010). VOSviewer was used to construct and examine several types of bibliometric networks, including co-authorship, and co-occurrence of keywords,. These analyses were conducted to uncover the intellectual structure, thematic development, and collaborative patterns within the field of Digital ESG Analytics.

First, a keyword co-occurrence analysis was performed to discover dominant themes and emerging research trends. Keywords from titles and author-supplied keyword fields were standardized (lowercased and merged for synonyms) before analysis. Only keywords meeting a minimum occurrence threshold ( $\geq 5$  appearances) were included to ensure that clusters reflected meaningful thematic patterns. The visualization generated color-coded clusters indicating the conceptual structure of the field, such as ESG reporting and disclosure analytics, AI-based sustainability assessment, and digital approaches to green finance.

Next, co-authorship analysis was applied at the author and country levels to explore patterns of research collaboration. This analysis highlights influential authors, identifies collaboration hubs, and visualizes the global distribution of research activities. Minimum document

thresholds ( $\geq 2$  publications per author) were applied to eliminate noise and strengthen the interpretability of the network.

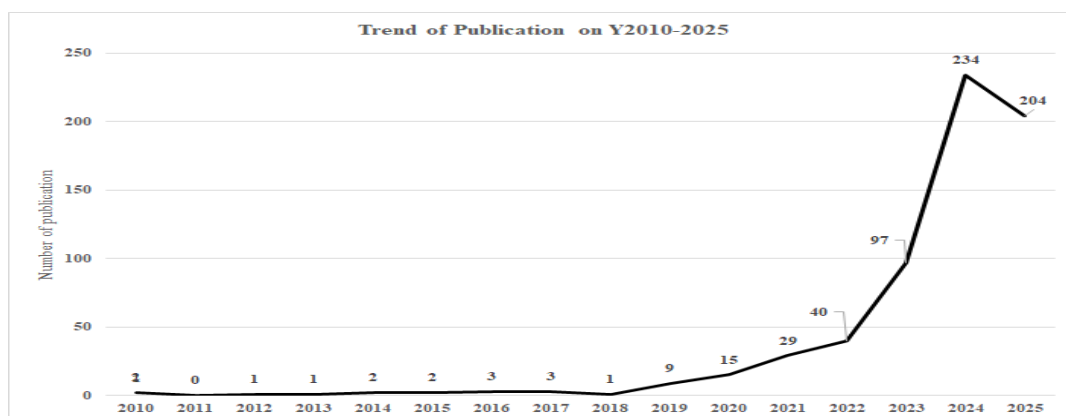
Across all analyses, the VOSviewer's clustering algorithm and visualization settings (full counting, normalization, attraction/repulsion parameters) were applied consistently to ensure comparability. The combination of keyword and authorship provides a comprehensive understanding of the structural and developmental patterns within the emerging field of AI-driven ESG analytics..

## 4. Findings and Discussions

To answer the research questions, this study conducted an Excels analysis and bibliometric analysis using VOSviewer based on 643 screened articles. Microsoft Excel was used to check the required documents according to PRISMA procedures and also to analyze publication trends. VOSviewer was employed to map co-authorship structures and keyword co-occurrence patterns, allowing a systematic identification of major themes and intellectual patterns within the Digital ESG Analytics field. The following sections present the key findings and their implications.

### 4.1 Trend of Publication

The trend of scientific publications on Digital ESG Analytics from 2010 to 2025 exhibits a dramatic growth pattern, as illustrated in Figure 1 below. During the early years (2010–2017), research output remained minimal, with annual publications fluctuating between zero and three articles. This period reflects the exploratory phase in which ESG reporting and digital technologies were still developing independently, with very limited integration between the two domains.



**Figure 2. Trend of Publication on Y2010-2025  
(Source: Author Analysis)**

Between 2018 and 2020, there was a discernible change, with one publication in 2018, nine in 2019, and fifteen in 2020. This rise is in line with the early adoption of analytical tools in sustainability reporting and the global mainstreaming of ESG in investment decision-making. The junction of ESG, AI, machine learning, and digital reporting was becoming a recognized academic topic, as seen by the continued acceleration of growth in 2021 and 2022, which saw 29 and 40 publications, respectively.

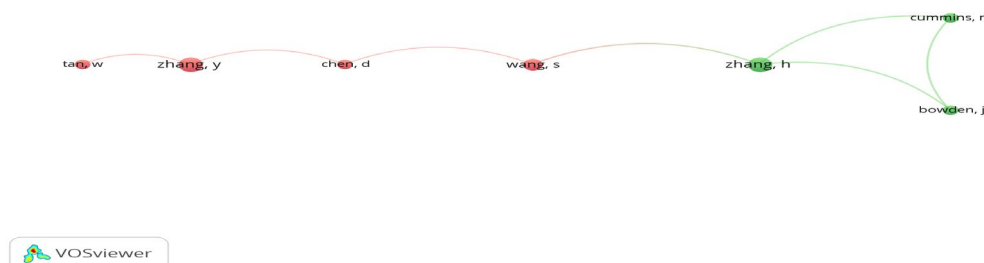
The graph clearly illustrates that the last three years saw the biggest spike. Publications surged

to 97 in 2023, more than doubled to 234 in 2024, and then reached 204 articles (including in-press and early-access publications) in 2025. In total, 535 out of 643 publications, or more than 80% of the total, were created between 2023 and 2025. Due to increased regulatory pressure, mandatory ESG disclosure requirements, technological advancements, and the widespread use of AI-based analytical tools in business and financial practices, Digital ESG Analytics has quickly become a significant research area, as evidenced by this exponential growth.

Overall, the papers' sharp upward trend emphasizes both the growing need for AI-driven sustainability solutions in the actual world and the academic urgency of comprehending Digital ESG Analytics. This pattern demonstrates that the subject has transitioned from an emerging specialty to a mainstream research priority, highlighting the importance and urgency of carrying out a thorough bibliometric analysis in this quickly developing field.

#### 4.2 Co-Author Network Analysis

The co-authorship analysis using VOSviewer (full counting, minimum of two documents per author) reveals a relatively compact collaboration structure in the Digital ESG Analytics field. From the 643 articles included in the dataset, only seven authors meet the threshold, forming two clearly separated clusters connected through a single collaboration path. Network visualization from VOSviewer showed on Figure 3 below :



**Figure 3. Co-author Network Visualization  
(Source: VOSviewer Analysis)**

There are 2 cluster of co-authorship i.e.:

The first cluster (red) consists of Tan, W; Zhang, Y; Chen, D; and Wang, S, arranged in a linear collaboration chain. Within this cluster, Zhang, Y and Chen, D appear as central nodes, suggesting repeated joint publications and a coordinating role in research related to AI-enabled ESG measurement and analytics. Their links with Tan, W and Wang, S indicate a primarily regional collaboration pattern, most likely within the same institutional or country context, with knowledge flows concentrated in a relatively tight scholarly circle.

The second cluster (green) brings together Zhang, H; Bowden, J; and Cummins, M, forming a small but dense triad with strong mutual connections. This group appears to represent an internationally oriented collaboration focusing on ESG, financial innovation, and digital reporting quality. Importantly, Zhang, H is directly linked to Wang, S from the red cluster, acting as a bridge between the two collaboration communities. This bridging position suggests the

beginnings of cross-regional integration in the field, even though the overall network remains sparse. Taken together, the co-authorship structure points to an emerging research domain with a few productive author teams, limited global integration, and significant opportunities for future international and interdisciplinary collaboration in Digital ESG Analytics..

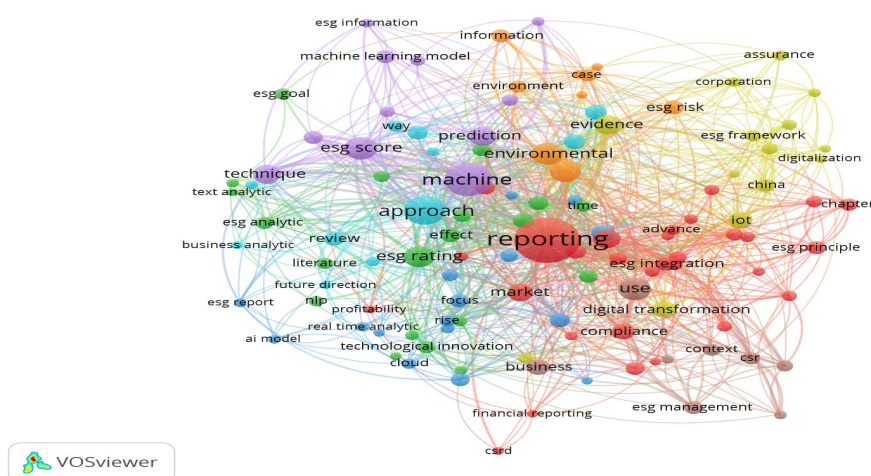
From this pattern, several conclusions can be drawn: 1). Early-stage field – The small number of recurring authors and weak global connectivity indicate that Digital ESG Analytics is still in an early stage of development, with no fully established global “elite” of core researchers yet; 2). Localized collaboration – Collaboration is largely localized within small teams or regional groups, rather than embedded in broad, international research networks; 3). Key bridging roles – Authors such as Zhang, H and Wang, S play bridging roles between clusters, suggesting they could become important connectors for future international and interdisciplinary projects; and 4). Opportunity for expansion – The sparsity of the network implies substantial room for expanding cross-country and cross-discipline collaborations, particularly between data science, finance, and sustainability scholars.

These findings support the view that Digital ESG Analytics is an emerging interdisciplinary field with growing, but still underdeveloped, research collaborations—offering clear opportunities for future network-building and joint research initiatives.

### 4.3 Keyword Co-occurrence Analysis

To examine the dominant concepts and thematic structures within the Digital ESG Analytics literature, a keyword co-occurrence analysis was conducted using VOSviewer. This technique maps how frequently key terms appear together across the 643 selected publications, offering insights into the conceptual relationships and research streams that shape the field. By setting a minimum occurrence threshold of five keywords, the analysis highlights the core topics, emerging themes, and the intellectual landscape underlying current scholarly discussions.

Figure 4 below displays the keyword co-occurrence network generated through VOSviewer to capture the dominant conceptual linkages within the Digital ESG Analytics literature. Using a minimum occurrence threshold of five keywords, the visualization opens for the main clusters, thematic interconnections, and high-impact concepts that form the core of this research area.



**Figure 4. Co-occurrence Network Visualization  
(Source: VOSviewer Analysis)**

The keyword co-occurrence visualization generated using VOSviewer (minimum occurrence of five keywords) exposes a dense and highly interconnected knowledge structure within the Digital ESG Analytics domain. The central node “reporting” dominates the map, indicating that ESG reporting practices, disclosure mechanisms, and digital reporting infrastructures constitute the intellectual core of this research area. Closely connected nodes such as “machine,” “approach,” “ESG rating,” “ESG score,” “environmental,” and “prediction” form a cluster of concepts related to AI-driven analytics, machine learning models, predictive assessments, and data-based ESG performance evaluation. The co-occurrence of terms such as “digital transformation,” “IoT,” “technological innovation,” “real-time analytics,” and “cloud” further indicates the centrality of advanced digital technologies in shaping contemporary ESG research.

Several thematic clusters emerge visibly in the network. The blue–green cluster revolves around AI, machine learning, prediction models, ESG rating systems, and data analytics—representing the technical foundation of Digital ESG Analytics. The yellow–brown cluster relates to governance, compliance, assurance, ESG frameworks, CSR, and corporate accountability, reflecting the institutional and regulatory dimension of ESG research. Meanwhile, the red cluster groups keywords such as “digital transformation,” “integration,” “use,” “context,” and “market,” suggesting a stream of studies focusing on the application of digital technologies in business ecosystems and sustainability strategy. Additional satellite nodes including “text analytics,” “NLP,” “review,” and “future direction” indicate growing methodological diversification, especially in using AI tools for ESG text analysis, sentiment analysis, and automated scoring.

This network highlight that Digital ESG Analytics is driven by three converging streams of research:

- a. AI- and ML-enabled ESG Measurement : Research focuses on machine learning techniques, prediction models, and automated scoring systems for ESG rating, performance forecasting, and environmental risk assessment.
- b. Digital Transformation of ESG Reporting: Studies explore how digital tools (IoT, cloud computing, real-time analytics) transform ESG disclosure practices, sustainability reporting quality, regulatory compliance, and financial transparency.
- c. Governance, Accountability, and Assurance: A governance-oriented cluster highlights interest in assurance mechanisms, ESG frameworks, compliance standards, corporate sustainability strategies, and stakeholder expectations.

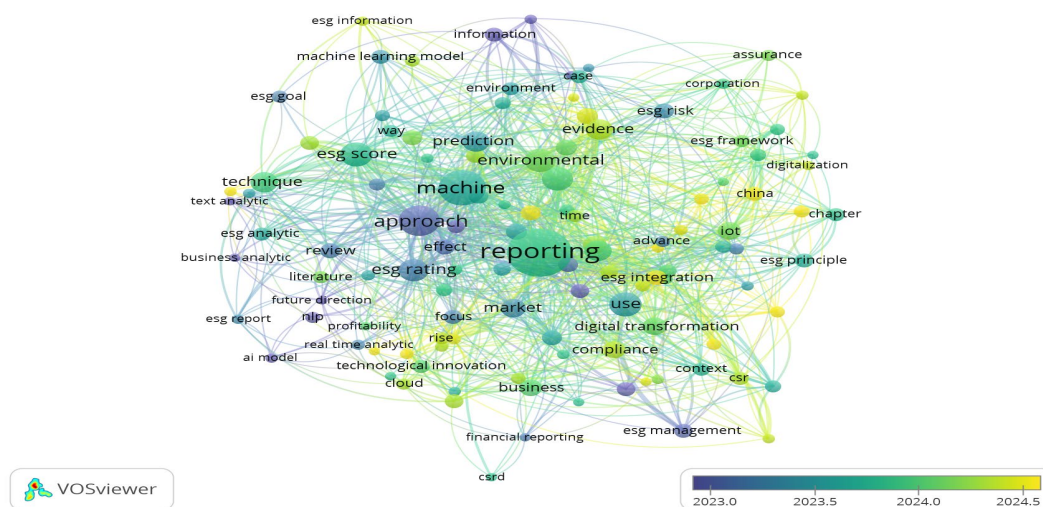
The strong interlinkages across clusters illustrate that the field is highly interdisciplinary, combining sustainability, finance, data science, and digital innovation.

From this co-occurrence we can also conclude several important things, namely:

- a. Reporting is the intellectual hub: ESG reporting stands at the center of the field, confirming that discussions about sustainability data quality, transparency, and standardization dominate current research.
- b. AI is becoming mainstream: The prominence of keywords such as machine, prediction, ESG score, rating, technique, real-time analytics, and NLP indicates rapid expansion of AI-based tools for sustainability assessment.
- c. Shift toward digital sustainability governance: Frequent appearance of terms like digital transformation, compliance, ESG management, and assurance shows how digitalization reshapes corporate governance and investor decision-making.

- d. Thematic maturity and emerging methods: The co-occurrence of text analytics, review, and future direction points to methodological consolidation and growth of literature reviews and analytical frameworks.

Figure 5 below presents the overlay visualization of the keyword co-occurrence network, showing the temporal evolution of key concepts within the Digital ESG Analytics literature. The color gradient indicates the average publication year associated with each keyword, with darker tones representing earlier research focus and lighter tones reflecting more recent themes. This visualization helps analyze how scholarly attention has shifted over time and which topics have emerged as new research frontiers



**Figure 5. Overlay Visualization Of The Keyword Co-Occurrence Network  
(Source: VOSviewer Analysis)**

The overlay map displays a clear chronological progression in the development of Digital ESG Analytics. Earlier studies, represented by darker blue and green clusters, predominantly focused on foundational themes such as “reporting,” “approach,” “ESG rating,” “environmental,” and “prediction.” These keywords indicate initial efforts to conceptualize ESG disclosure, establish measurement approaches, and explore basic predictive models for sustainability assessment.

In contrast, more recent publications (highlighted in yellow) exhibit a growing emphasis on advanced digital technologies and governance-related constructs. Terms such as “digitalization,” “IoT,” “assurance,” “ESG framework,” “technological innovation,” and “text analytic” suggest a shift toward integrating cutting-edge analytical tools with corporate reporting and risk management systems. The emergence of keywords like “NLP,” “machine learning model,” “real-time analytics,” and “ESG information” indicates the increasing adoption of AI-driven techniques for automating ESG evaluation and extracting insights from unstructured data.

Moreover, the presence of “compliance,” “ESG management,” “context,” and “corporation” in lighter colors reflects a strengthening link between digital technologies and broader corporate governance, signaling that ESG analytics is increasingly embedded in organizational decision-making, regulatory reporting, and strategic sustainability initiatives.

From this density co-occurrence network, we can also conclude several important things,

namely:

- Shift Toward AI and Real-Time Digital Analytics: Newer keywords such as text analytic, NLP, machine learning model, and real-time analytics indicate a rapid expansion of AI-driven approaches. ESG research is moving beyond descriptive reporting towards automated assessment and predictive analytics.
- Digital Transformation is the Current Research Frontier: Frequent recent keywords like digitalization, IoT, technological innovation, and cloud demonstrate a strong trend toward integrating ESG frameworks with Industry 4.0 technologies. This highlights a shift from traditional sustainability accounting to “digitally intelligent” ESG ecosystems.
- Strengthening Governance and Assurance Themes: The rise of keywords such as assurance, compliance, ESG framework, ESG management reflects growing regulatory pressure and the need for verification, transparency, and standardization in digital ESG reporting.
- Increasing Interdisciplinarity: The emergence of methodological keywords (review, literature, chapter, technique) alongside technical and governance terms shows that the field is attracting scholars from information systems, accounting, data science, finance, and sustainability domains simultaneously.
- Geographical and Contextual Factors are Emerging: The appearance of recent terms like China, corporation, and context suggests growing attention toward contextual, cross-country, and market-specific ESG analysis.

The overlay co-occurrence map reveals an evolving research landscape shifting from foundational ESG reporting and rating discussions toward advanced AI-enabled analytics, digital transformation technologies, and governance-oriented themes. This temporal progression highlights how Digital ESG Analytics is becoming more sophisticated, interdisciplinary, and deeply integrated into organizational digital ecosystems—marking it as a rapidly emerging frontier in sustainable business and financial innovation.

#### 4.4 Thematic Analysis

To provide a clearer overview of the conceptual structure within the Digital ESG Analytics literature, the results of the keyword co-occurrence analysis were further grouped into thematic clusters. Table 1 below summarizes the eight major clusters identified through VOSviewer, showing the distribution of keywords and the dominant themes that characterize each research stream. These clusters reflect the multidimensional nature of the field, combining digital technologies, ESG measurement, sustainability governance, financial innovation, and organizational practices.

**Tabel 1. Thematic Clusters of Digital ESG Analytics**

| Cluster | Item | Keyword                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1       | 30   | advance, advance daya analytic, ai analytic, ai driven analytic, bank, banking, blockchain technology, chapter, compliance, conceptual framework, contribution, corporate governance, csrd, danantara, esg criterium, esg integration, esg invensting, esg metric, esg principle, esg standard, evolution, financial reporting, green bond, green finance, instance, market, profitability, real time, reporting, sustainable business practices |

| Cluster | Item | Keyword                                                                                                                                                                                                                                                                                                                  |
|---------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2       | 20   | adoption, in application, corporate esg performance, corporate sustainability, effect, esg analytic, esg goal, esg practice, esg rating, evaluation, literature, moderating role, natural language process, nlp, relationship, sentiment analysis, sustainable development goal, technological innovation, text analytic |
| 3       | 16   | ai algorithm, ai driven esg analytic, air model, automation, cloud, esg report, esg strategy, financial institution, financial service, focus, generative ai, investment decision, process, real time analytic, rise, sustainable development                                                                            |
| 4       | 14   | assurance, china, corporation, digital technology, digital transformation, digitalization, esg framework, esg initiative, evidence, help, internet, iot, smes,thing                                                                                                                                                      |
| 5       | 11   | article, concept, esg controversy, esg information, esg score, machine, machine learning algorithm, machine learning model, prediction, score, technique                                                                                                                                                                 |
| 6       | 11   | ai adoption, alignment, process, business analytic, esg analysis, future direction, gap, greenwashing, quality, review, way                                                                                                                                                                                              |
| 7       | 9    | ai technique, case, environment, environmental, esg compliance, esg risk, information, social, society                                                                                                                                                                                                                   |
| 8       | 8    | business, context, corporate social responsibility, csr, effectiveness, energy, esg management, use                                                                                                                                                                                                                      |

The explanation of the cluster according to the table above is:

- Cluster 1 – Digital ESG Governance & Green Finance Infrastructure** : It represents research on how advanced analytics and AI are embedded into the governance and reporting infrastructure of financial institutions. The emphasis on CSRD, ESG standards, and green finance instruments indicates a strong focus on regulatory-driven ESG disclosure, technology-enabled transparency, and the design of sustainable financial products.
- Cluster 2 – AI-Based ESG Performance Measurement & Text Analytics**: Studies in this cluster typically use NLP and sentiment analysis to extract ESG signals from reports, news, and corporate communication and link them to corporate sustainability outcomes, moderating effects, or ESG goal achievement.
- Cluster 3 – AI, Generative AI and ESG Strategy in Financial Institutions**: The focus is on algorithmic models deployed in cloud environments, real-time analytics, and the integration of sustainability objectives into financial decision-making.
- Cluster 4 – Digital Transformation, IoT and ESG Initiatives in Corporations and SMEs**: It reflects empirical evidence on how firms adopt digital technologies to implement ESG frameworks, improve assurance and monitoring, and respond to stakeholder and regulatory expectations
- Cluster 5 – Machine-Learning-Driven ESG Scoring and Controversies**: This cluster also acknowledges ESG controversy, suggesting that scholars are not only building models but also examining the limitations, biases, and debates around algorithmic ESG information and scoring techniques.
- Cluster 6 – Meta-Studies, Gaps and Greenwashing in ESG Analytics**: It highlights discussions on alignment between AI and ESG objectives, identifies research gaps and future directions, and pays particular attention to issues of data quality and greenwashing in ESG claims.

- g. Cluster 7 – **ESG Risk, Compliance and Societal Implications**: Studies here often use AI techniques in case-based analyses to understand how ESG risk and compliance affect stakeholders and social outcomes.
- h. Cluster 8 – **CSR, ESG Management and Business Context** : This cluster represents work at the intersection of CSR and ESG management, examining how ESG tools and practices are used in different business and energy contexts, and how effective they are in supporting sustainability strategies at the firm level.

Overall, the thematic clusters reveal that Digital ESG Analytics is characterized by a diverse and interconnected set of research streams that span technology, governance, analytics, and corporate practice. Together, these clusters highlight the field’s evolution from basic ESG reporting toward more sophisticated, AI-enabled measurement frameworks and digitally supported sustainability strategies, providing a solid foundation for understanding current developments and identifying future research opportunities.

To complement the thematic cluster mapping, this study further identifies the 20 most relevant keywords based on VOSviewer’s relevance score and occurrence frequency. Several terms that appeared in the raw extraction—such as “thing”, “chapter”, and other non-conceptual words—were removed to maintain analytical clarity and ensure that only substantive, domain-specific keywords were included. The resulting list represents the most influential concepts shaping the current discourse on Digital ESG Analytics and provides a refined foundation for interpreting emerging trends in the literature (Table 2 below).

**Table 2. Twenty most relevant keywords based on VOSviewer’s relevance score and occurrence frequency**

| No | Keyword                           | Occurrences | Relevance |
|----|-----------------------------------|-------------|-----------|
| 1  | Sustainable development goal      | 5           | 2.57      |
| 2  | Investment decision               | 11          | 2.21      |
| 3  | Danantara                         | 9           | 2.18      |
| 4  | ESG compliance                    | 6           | 2.04      |
| 5  | ESG analysis                      | 6           | 1.92      |
| 6  | ESG goal                          | 9           | 1.91      |
| 7  | SMEs                              | 8           | 1.89      |
| 8  | AI application                    | 7           | 1.84      |
| 9  | AI algorithm                      | 8           | 1.79      |
| 10 | Business analytic                 | 5           | 1.72      |
| 11 | NLP (natural language processing) | 8           | 1.65      |
| 12 | ESG management                    | 13          | 1.63      |
| 13 | Financial institution             | 9           | 1.54      |
| 14 | Digital technology                | 6           | 1.43      |
| 15 | Corporate sustainability          | 6           | 1.43      |
| 16 | AI model                          | 6           | 1.42      |
| 17 | Advanced data analytic            | 5           | 1.39      |
| 18 | Machine Learning algorithm        | 8           | 1,35      |
| 19 | Technological innovation          | 10          | 1.15      |
| 20 | ESG Information                   | 6           | 1.14      |

The top 20 keywords highlight the growing integration of digital technologies with core ESG

practices. Terms such as “sustainable development goal,” “investment decision,” “ESG compliance,” “ESG analysis,” and “ESG management” illustrate that current research is strongly focused on how digital tools support sustainability targets, improve reporting quality, and enhance corporate decision-making. The appearance of SMEs, financial institutions, and corporate sustainability also indicates that Digital ESG Analytics is becoming relevant across diverse organizational contexts, not only large corporations.

At the same time, the prominence of technology-oriented keywords—such as AI application, AI algorithm, AI model, machine learning algorithm, NLP, advanced data analytic, technological innovation, and digital technology—demonstrates that artificial intelligence and data analytics are now central to ESG research. These keywords collectively suggest that the field is rapidly shifting toward a data-driven and AI-enabled approach, where automation, predictive modelling, and text analytics are increasingly used to support ESG reporting, performance assessment, and transparency.

#### *4.4 Research Fronts and Thematic Developments in Digital ESG Analytics*

Digital ESG Analytics is shaped by a number of interrelated thematic domains that indicate the field's rapid evolution, according to keyword co-occurrence and cluster-based mapping. The foundations of ESG, such as ESG compliance, ESG analysis, ESG aim, and corporate sustainability, are the focus of large clusters that reflect ongoing attention to sustainability performance, regulatory alignment, and ethical business practices. Artificial intelligence has evolved from a supporting tool to a primary driver of innovation in ESG measurement, reporting, and decision-making, as evidenced by the coexistence of these themes with new technology-oriented fronts such as AI application, AI model, machine learning algorithm, NLP, and advanced data analytics. The prevalence of terms like "financial institution," "technological innovation," and "investment decision" further indicates that digital analytics is being incorporated more and more into conventional financial analysis and sustainable investment plans.

Strong connections to NLP, sentiment analysis, and text analytics further demonstrate the mapping's rising interest in automated analysis of large-scale ESG data. The extraction of real-time insights from unstructured sustainability disclosures, news articles, and regulatory papers is the subject of a research horizon represented by these approaches. Digital ESG solutions are becoming relevant to smaller businesses and a variety of geographic contexts, as evidenced by keywords like SMEs, ESG management, and ESG information. Another emerging theme is organizational and contextual applications. Clusters that include green finance, green bonds, and ESG score also highlight financial innovations as a key component in the creation of sustainable practices that are facilitated by digital technology.

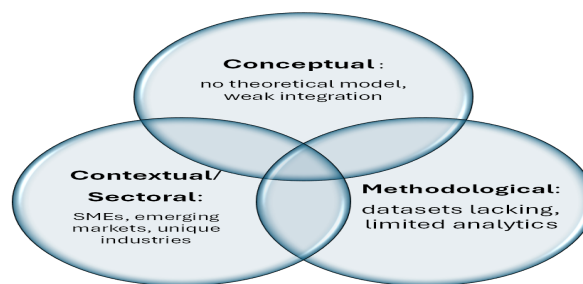
When taken as a whole, these thematic patterns display that the field of Digital ESG Analytics research is growing in two primary directions:

- a. methodological developments fueled by AI, machine learning, and data-driven automation; and
- b. applied developments aimed at enhancing ESG transparency, regulatory compliance, and sustainable financial decision-making. These fronts' convergence highlights a fast developing and expanding discipline, laying the groundwork for future study on more complex, real-time, and ethically grounded ESG analytics.

#### *4.5. Research Gaps and Future Directions*

Digital ESG Analytics is a quickly growing subject, according to the bibliometric mapping of 643 publications; yet, the distribution of thematic clusters and keyword patterns also reveals a number of conceptual, methodological, and contextual deficiencies that limit the domain's maturity. As businesses, authorities, and financial institutions rely more and more on AI-driven sustainability analytics, these gaps offer crucial information for developing a future research agenda. Therefore, identifying these gaps is crucial for both increasing scientific knowledge and assisting practitioners and policymakers in implementing strong and ethical digital ESG practices.

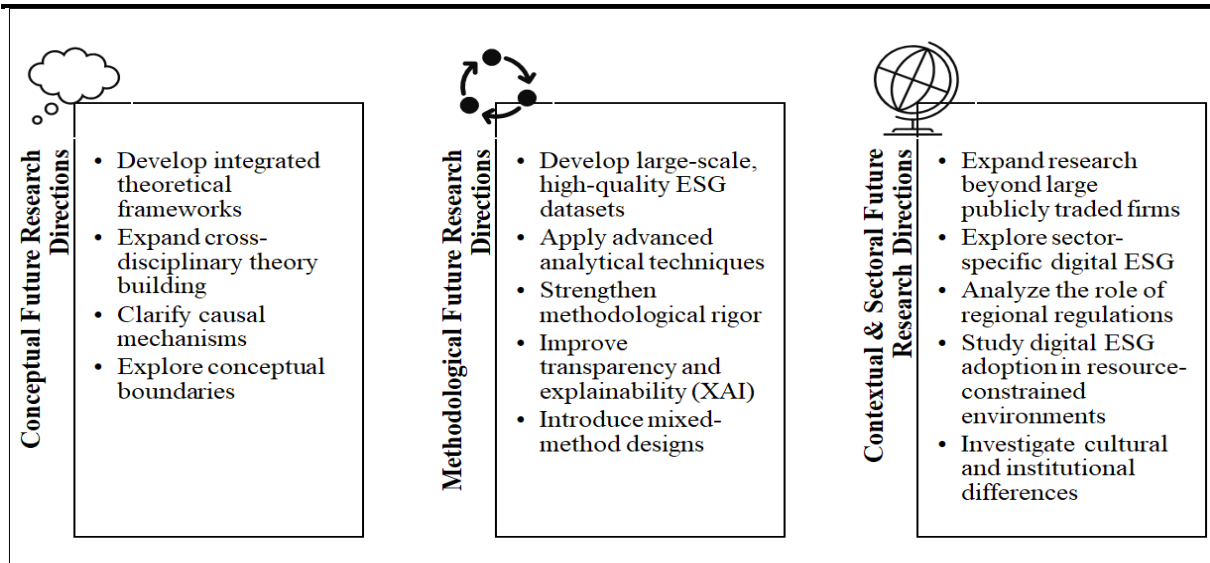
To complement the bibliometric findings, this study synthesizes the major research gaps in Digital ESG Analytics into a concise three-dimensional framework, highlighting conceptual, methodological, and contextual/sectoral limitations that consistently emerged across the 643 analyzed publications. The diagram visualizes how existing studies lack strong theoretical grounding, rely on limited or fragmented analytical methods, and remain concentrated in specific regions and large firms, leaving SMEs and emerging-market contexts underexplored. Together, these gaps shape the key opportunities for future research at the intersection of digital technologies and ESG.



**Figure 6. Venn Diagram of Research Gaps**

The Venn diagram illustrates that research gaps in Digital ESG Analytics are not isolated but interconnected across three dimensions. Conceptual gaps arise from the absence of unified theoretical models and weak linkages between ESG domains and digital technologies. Methodological gaps reflect the limited availability of high-quality datasets, inconsistent analytical techniques, and a heavy reliance on descriptive rather than advanced analytical methods. Contextual and sectoral gaps fair that most studies focus on large corporations and developed markets, while SMEs, emerging economies, and industry-specific ESG challenges remain understudied. Collectively, these gaps indicate the need for more integrated theory-building, richer data infrastructures, and broader contextual coverage in future research.

Building on the research gaps shown in the Venn diagram, it is evident that strategic expansion across conceptual, methodological, and contextual dimensions is necessary for the future development of Digital ESG Analytics rather than merely incremental improvement. In addition to highlighting areas where the field is currently limited, the gaps also point to significant prospects for further research to further the field. Converting these gaps into specific Future Research Directions that may direct academics, decision-makers, and practitioners is the next stage. In order to ensure that future research not only closes current gaps but also speeds up innovation in the field of digital ESG analytics, the upcoming diagram arranges these opportunities into logical thematic routes.



**Figure 7. Future Research Directions in Digital ESG Analytics  
(Source: Author Analysis)**

In summary, the future research agenda derived from this study highlights the need for a more unified theoretical base, stronger methodological rigor, and broader contextual exploration within Digital ESG Analytics. By addressing these conceptual, methodological, and sectoral gaps, upcoming research can move beyond fragmented insights toward a more integrated, data-driven, and globally relevant understanding of how digital technologies reshape ESG measurement, reporting, and decision-making. This agenda provides a structured pathway for scholars to advance the field and build a more mature and impactful research domain.

This study provides three major academic contributions. First, it offers a comprehensive bibliometric mapping of 643 publications that systematically identifies the evolution, thematic clusters, and research fronts in Digital ESG Analytics—an area that previously lacked structured synthesis. Second, the study contributes a methodological advancement by combining keyword co-occurrence, network mapping, and cluster-based thematic interpretation to expose conceptual and methodological fragmentation in the field. Third, the findings enrich the theoretical foundations of Digital ESG research by highlighting unaddressed conceptual gaps, underdeveloped integrative models, and emerging analytical paradigms such as AI-driven ESG evaluation and digital sustainability frameworks.

The findings offer several practical implications. Organizations can use the identified thematic clusters—such as AI-driven ESG analytics, digital transformation, and ESG reporting automation—to guide the adoption of digital tools that enhance transparency and compliance. Policymakers may benefit from understanding the global shift toward data-centric sustainability reporting, supporting the development of standardized digital ESG frameworks. For practitioners and ESG consultants, this study highlights emerging analytical techniques, including NLP-based sentiment analysis, real-time analytics, and generative AI, which can significantly improve the accuracy and efficiency of ESG evaluations.

## 5. Conclusion

This study synthesizes evidence from 643 peer-reviewed publications published between 2010 and 2025 to provide a comprehensive bibliometric mapping of the rapidly developing field of

Digital ESG Analytics. The analysis shows that the field has evolved from an exploratory niche into a significant scholarly and practice-oriented domain, marked by a sharp rise in research output beginning in 2023. This surge reflects the increasing integration of artificial intelligence, machine learning, and big data technologies into ESG assessment, as well as the global push for transparent, data-driven sustainability practices.

Keyword co-occurrence analysis and thematic clustering reveal eight dominant research clusters encompassing ESG reporting, AI-driven analytics, digital transformation, technological innovation, sustainability goals, machine learning models, ESG performance, and sector-specific applications. Collectively, these clusters signal a shift toward predictive, automated, and integrative ESG solutions. The overlay visualization further demonstrates the temporal progression of research themes—from early descriptive ESG discussions to advanced topics such as generative AI, real-time analytics, NLP-based sentiment analysis, and digital ESG integration.

The co-author network analysis shows that collaboration patterns remain highly fragmented, with only a few regional clusters—particularly among Chinese scholars—forming noticeable cooperation networks. This highlights the need for stronger international collaboration to broaden scientific perspectives and mitigate regulatory or geographic biases in the literature.

In addressing the final research question, the study identifies three major categories of research gaps:

- 1) Conceptual gaps, including the absence of integrated theoretical models and limited cross-disciplinary synthesis;
- 2) Methodological gaps, such as the scarcity of high-quality ESG datasets, weak methodological rigor, and the underutilization of advanced analytical tools; and
- 3) Contextual and sectoral gaps, including limited research on SMEs, emerging markets, resource-constrained sectors, and non-Western regulatory environments.

The proposed future research directions—including the development of theoretical frameworks for digital ESG, greater methodological transparency and explainability (XAI), broader sectoral and geographical coverage, and the adoption of mixed-method and multi-stakeholder approaches—directly respond to these gaps.

Overall, this bibliometric analysis offers a consolidated understanding of the evolution, thematic structure, and research frontiers of Digital ESG Analytics. The findings are expected to guide scholars, practitioners, and policymakers toward more rigorous, innovative, and contextually relevant research that strengthens the role of digital technologies in sustainability governance..

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