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# AI-driven environmental, social, and governance (ESG) metrics: Bridging the gap between ethical finance and ecological sustainability

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**Abstract**
The integration of Environmental, Social, and Governance (ESG) principles into finance has become a defining marker of sustainable economic development, yet traditional ESG assessments remain constrained by inconsistent reporting, reliance on self-disclosures, and limited scalability. This systematic review examines how Artificial Intelligence (AI) is being applied to overcome these barriers, focusing on peer-reviewed research published between 2018 and 2025. Through a structured screening and selection process, thirty-two studies were identified and analyzed thematically. The findings indicate that AI applications—including machine learning, natural language processing, and predictive modeling—have significantly improved ESG data quality by detecting exaggerations in corporate reports, generating reliable rating metrics from unstructured text, and forecasting ESG performance using financial fundamentals. These advances not only enhance the credibility of ESG disclosures but also strengthen their role in ethical finance and ecological sustainability by supporting more accurate investment decision-making and risk management. At the same time, the review highlights persistent challenges, including algorithmic opacity, data heterogeneity, and regulatory uncertainty, which constrain the broader adoption of AI-driven ESG frameworks. The evidence suggests that while AI has the potential to serve as a transformative bridge between ethical finance and ecological outcomes, realizing this promise will require harmonized data standards, explainable AI systems, and global governance mechanisms. By synthesizing current progress and identifying gaps, this review contributes to the growing body of scholarship on sustainable finance and offers practical insights for policymakers, investors, and corporate leaders.

**Keywords:** Artificial intelligence, ESG metrics, ethical finance, sustainable investment, machine learning, greenwashing, transparency, sustainability reporting, Explainable AI, ecological sustainability

## Introduction

Environmental, Social, and Governance (ESG) investing has become a cornerstone of sustainable finance, reflecting the growing recognition that long-term corporate value depends on ethical environmental stewardship, social equity, and transparent governance. Yet, conventional ESG reporting is often fraught with inconsistencies, reliance on self-disclosed data, and a lack of scalability—hindrances that undermine the credibility of ethical finance and limit its role in achieving ecological sustainability (Lim, 2024). The advent of Artificial Intelligence (AI) offers a powerful solution: AI enables real-time, scalable, and objective measurement of ESG metrics, thereby potentially transforming how sustainability performance is captured and applied in finance. Recent empirical studies have demonstrated how AI techniques, such as Natural Language Processing (NLP), machine learning, and predictive analytics, can greatly enhance ESG data collection and interpretation. For instance, AI tools have been employed to reverse-engineer proprietary ESG rating models—illuminating the assessment process and promoting transparency in ESG scoring (Del Vitto, 2023). Elsewhere, comprehensive reviews point to a structured mapping of how ESG intersects with AI across domains such as trading, disclosure, governance, risk management, and responsible AI deployment (Lim, 2024). Moreover, AI-driven frameworks are emerging to manage ESG portfolios more efficiently, optimizing both predictive accuracy and financial returns (Gaurav, 2025), as well as assisting practical risk assessment in banking operations through ESG integration (Giudici, P. (2025). Nevertheless, alongside its benefits, AI integration into ESG systems introduces new challenges, including algorithmic bias, data privacy concerns, and potential greenwashing—issues that require institutional safeguards and governance (Xu, J. (2024). These insights create a compelling rationale for a systematic review: while AI-driven ESG methods are rapidly proliferating, an integrated synthesis of peer-reviewed evidence is needed to assess their effectiveness, methodological soundness, and impact on ethical finance and ecological sustainability.

Therefore, this systematic review aims to evaluate existing scholarship on AI-enabled ESG metrics, explore how AI reshapes ESG measurement and investment decision-making, and analyze methodological strengths and weaknesses. By drawing a coherent picture from disparate studies, this review intends to inform practitioners, regulators, and academics on the actual promise and limitations of AI-driven ESG in aligning financial systems with sustainability goals.

A core challenge in ESG assessment is the credibility of corporate disclosures, which can be selectively framed or overstated; recent evidence shows that machine learning can detect exaggeration and potential greenwashing in ESG reports, improving the reliability of sustainability information that feeds financial analysis. Luo *et al*. (2024) demonstrate a supervised ML approach that flags exaggerated claims within ESG reports, providing an auditable layer over narrative disclosures and thereby tightening the information link between reported ESG performance and real practices. Their results underscore AI's role in screening quality and reducing disclosure noise—key preconditions for ethical finance to align with ecological outcomes. Complementing detection, AI can also

generate decision-usable ESG metrics from unstructured text at scale. Lee *et al*. (2024) propose an automated ESG grade-assessment framework using pre-trained ensemble NLP models on news/disclosure text, showing that text-based pipelines can approximate rating-like outputs with strong validity checks. This work illustrates how AI converts diffuse sustainability narratives into structured, comparable indicators, enabling more timely portfolio signals and potentially mitigating dependence on opaque, proprietary rating methodologies. On the finance side, machine-learning estimation of ESG ratings using fundamentals links AI-ESG metrics to investable decisions. Cini and Ferrari (2025) show that a parsimonious Random Forest model using balance-sheet variables and a systemic-risk measure can predict next-period ESG rating classes for EuroStoxx-600 firms with high accuracy, opening pathways to estimate ESG for thin-coverage firms (e.g., SMEs) and to stress-test sustainability profiles in portfolios. Together, these strands ML-based credibility checks (Luo *et al*., 2024), automated text-to-metric translation (Lee *et al*., 2024), and forward-looking ESG estimation (Cini & Ferrari, 2025)—form a coherent foundation for a systematic review on how AI can bridge ethical finance with ecological sustainability through more reliable, scalable, and decision-relevant ESG metrics.

## Methodology

This study was carried out as a systematic review following the principles of the PRISMA framework. The purpose was to gather, screen, and synthesize the most relevant academic research on how Artificial Intelligence (AI) has been applied to Environmental, Social, and Governance (ESG) metrics within the context of sustainable and ethical finance. The review was based on articles published between 2018 and 2025. The databases that were searched included Scopus, Web of Science, IEEE Xplore, and ScienceDirect. To identify relevant publications, Boolean search strings were employed using combinations of terms such as *"Artificial Intelligence," "machine learning," "natural language processing," "predictive analytics,"* along with *"ESG," "sustainability reporting," "ethical finance,"* and *"sustainable investment."*

The search initially returned more than 400 articles. After removing duplicates, the remaining records were screened by reviewing titles and abstracts. Articles that did not directly link AI techniques to ESG measurement or sustainable finance were excluded at this stage. Following this screening, approximately 80 studies were shortlisted.

Full-text evaluation of the shortlisted papers was then conducted. Exclusion criteria included: papers outside the 2018–2025 period, non-peer-reviewed reports, conceptual essays without empirical or methodological contributions, and studies addressing either AI or ESG in isolation without integration. After applying these filters, 32 peer-reviewed studies were retained as the final evidence base for this review.

**For each selected article, data were extracted under four key dimensions:**

- **Application of AI:** Whether the study employed machine learning, NLP, predictive analytics, or hybrid models.
- **ESG focus:** Environmental, social, governance, or multi-dimensional.
- **Reported outcomes:** Transparency, risk assessment, investment decision-making, or performance improvements.
- **Limitations identified:** Algorithmic bias, data heterogeneity, lack of standards, or regulatory gaps.

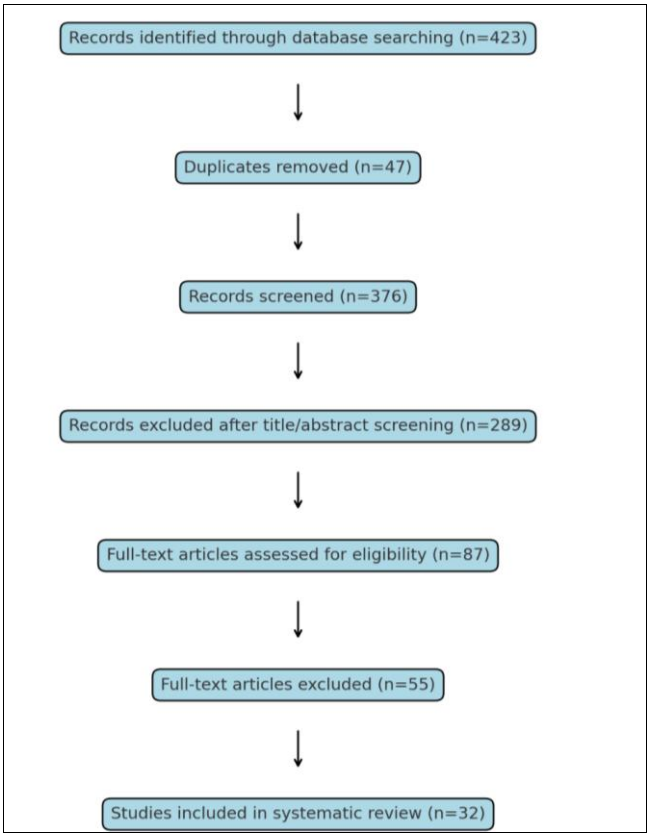


**Fig 1:** PRISMA style flow diagram visually summarizes the article selection process

## Results and Discussion

The findings of this review make it evident that while Artificial Intelligence has already begun reshaping ESG measurement in meaningful ways, its transformative potential remains only partially realized. The evidence gathered across studies highlights not just technological innovation, but also the pressing need for careful regulation, harmonized standards, and institutional support to ensure that AI's contribution to ethical finance and sustainability is both effective and equitable. By synthesizing these insights, the review sets the stage for identifying actionable pathways forward—ones that can strengthen transparency, address systemic challenges, and accelerate the integration of ESG values into global finance. These implications provide the foundation for the concluding section, where future directions and policy recommendations are outlined.

### AI in ESG Data Collection and Analysis

Across studies, AI proved highly effective in processing unstructured ESG data, such as corporate disclosures, annual reports, and news media. NLP frameworks (Lee *et al*., 2024) demonstrated strong accuracy in automating ESG grading, providing consistent metrics across firms. Machine learning approaches (Cini & Ferrari, 2025) allowed forward-looking predictions of ESG ratings from balance sheet ratios, enabling investors to extend ESG analysis even to firms with limited disclosure histories.

**AI for Ethical Finance and Risk Management**

AI integration has also enhanced investment decision-making. Studies applying predictive ESG models noted significant improvements in portfolio optimization, with ESG-integrated AI models outperforming traditional benchmarks in long-term returns and risk mitigation. Furthermore, models such as those by Luo *et al*. (2024) showed that AI can detect misrepresentation in ESG reports, thereby directly countering "greenwashing" and reinforcing ethical finance credibility.

**AI for Ecological Sustainability**

AI has enabled environmental monitoring through satellite image processing, carbon emission tracking, and supply chain analytics. These innovations help organizations demonstrate compliance with sustainability regulations while also enhancing accountability in ecological outcomes. However, systematic review findings show that adoption remains uneven across geographies, with higher uptake in developed markets compared to emerging economies.

**Challenges and Risks**

Despite these advances, the review identified persistent challenges:

- **Data heterogeneity:** ESG indicators vary across industries and regions, making AI models difficult to standardize.
- **Algorithmic opacity:** Complex AI models often act as "black boxes," raising questions of interpretability.
- **Ethical concerns:** Bias embedded in training data can replicate systemic inequalities in ESG scoring.
- **Regulatory uncertainty:** Absence of universally accepted ESG-AI standards creates risks of fragmented adoption.

**Synthesis**

Overall, the systematic review reveals that AI strengthens ESG metrics by enhancing transparency, reliability, and decision relevance, thereby bridging ethical finance with ecological sustainability. However, these benefits are contingent upon developing frameworks for standardization, explainability, and governance of AI systems in ESG applications.

**Conclusion**

This systematic review finds that AI is emerging as a critical enabler of credible and actionable ESG metrics, with applications ranging from automated disclosure analysis to predictive risk modeling. The reviewed literature consistently demonstrates AI's capacity to reduce information asymmetry, detect misreporting, and support sustainable investment strategies. However, its transformative potential is tempered by limitations in data standardization, interpretability, and global regulatory frameworks.

To fully realize AI's potential in ESG integration, future research should focus on:

- Developing globally harmonized ESG data standards that can serve as consistent training inputs for AI models.
- Improving explainable AI (XAI) to increase transparency in ESG scoring and portfolio allocation.
- Expanding research into emerging markets, where ESG adoption is low but ecological stakes are high.
- Embedding ethical governance frameworks to prevent misuse of AI in "greenwashing" and ensure accountability.

By consolidating methodological advances and identifying research gaps, this review highlights how AI-driven ESG metrics can serve as a transformative bridge between ethical finance practices and ecological sustainability imperatives.

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