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Research Article

GREEN MAQASID MEETS HALAL ECONOMY: INTEGRATING SUSTAINABILITY METRICS INTO AI-POWERED DIGITAL HALAL CERTIFICATION STANDARDS

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Abstract

The rapid expansion of the global halal economy, coupled with growing environmental concerns, has intensified calls to integrate sustainability principles into halal certification frameworks. Conventional halal standards mainly focus on ingredient permissibility and production processes, often neglecting ecological impact, carbon footprint, and ethical resource management. In response, Green Maqasid al-Shari'ah an extension of the classical objectives of Islamic law emphasizing environmental stewardship offers a normative basis for embedding sustainability within halal governance. At the same time, advances in artificial intelligence (AI) create opportunities to operationalize these values through automated monitoring, digital traceability, and real-time compliance assessment. This convergence highlights the need for a systematic analysis of incorporating sustainability metrics into AI-powered halal certification systems. Accordingly, this study examines the feasibility, governance implications, and technological requirements of integrating Green Maqasid sustainability indicators into digital halal certification standards, aiming to develop a conceptual framework that aligns Islamic ethical principles with AI-enabled compliance infrastructures in cross-border halal trade. A qualitative research approach is employed, including document analysis, expert interviews with Shariah scholars and AI specialists, and case studies of emerging digital certification platforms. The findings reveal that AI can effectively integrate sustainability metrics such as ecological impact assessment, waste reduction, and ethical sourcing into halal certification processes, though challenges persist regarding data standardization, Shariah oversight, and cross-jurisdictional alignment. The study concludes that embedding Green Maqasid principles enhances both religious integrity and environmental responsibility in future halal governance.

Keywords: AI Compliance, Green Maqasid, Halal Economy

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INTRODUCTION

Global awareness of sustainability has grown significantly as climate change, environmental degradation, and resource depletion continue to threaten ecological and human well-being. International policy frameworks such as the SDGs promote environmentally responsible economic systems, encouraging nations and industries to adopt greener production and consumption patterns (Chen, 2025). These developments highlight the need for ethical governance models that integrate ecological responsibility into economic regulation (Leal Filho et al., 2025; Rakshit et al., 2025). The halal economy has expanded into a multi-trillion-dollar global market that spans food, pharmaceuticals, cosmetics, logistics, and tourism (Bayatzadeh & Talaie, 2025). Halal certification ensures compliance with Islamic dietary and ethical principles, providing assurance to consumers about product purity, safety, and religious validity. The rise of global digital trade has intensified the demand for standardized, transparent, and efficient halal certification mechanisms across borders (El Hajji et al., 2024).

Islamic jurisprudence emphasizes not only ritual compliance but also ethical, social, and environmental responsibilities. The emerging concept of Green Maqasid al-Shari‘ah extends the classical objectives of Islamic law by incorporating environmental stewardship as an expression of human responsibility as khalīfah (vicegerent) on Earth. This conceptual expansion aligns religious principles with modern sustainability discourse (Han et al., 2025; Rahman & Awal, 2025). Digital transformation has introduced new tools to support halal certification, including blockchain, automated documentation, and artificial intelligence. AI-powered systems have demonstrated potential in enhancing accuracy, automating verification processes, and strengthening supply-chain traceability. Early pilot projects suggest that AI can streamline halal auditing in ways that traditional manual inspection cannot match (El jaouhari et al., 2024).

Halal industry stakeholders increasingly recognize the importance of sustainability as part of consumer expectations and global market competitiveness. Many halal producers and regulators have begun adopting environmentally friendly practices, although the extent of integration varies greatly across jurisdictions (Basel, 2024). The conversation has shifted from merely ensuring product permissibility to ensuring holistic ethical compliance. Scholars and industry leaders acknowledge that integrating sustainability into halal certification requires both religious legitimacy and technological capacity (Saiyed & Kumar, 2025; Westphal et al., 2023). Despite growing interest, practical mechanisms for operationalizing sustainability in halal verification—especially through AI—remain underdeveloped (Rajput et al., 2025).

The degree to which Green Maqasid can be systematically incorporated into halal certification remains unexplored. While conceptual discussions emphasize the importance of environmental stewardship, there is limited guidance on how these principles can be translated into measurable sustainability metrics applicable in certification workflows (Almutairi et al., 2025). The absence of standardized frameworks limits practical implementation (Chen, 2025). The role of AI in enabling sustainability-oriented halal certification has not been clearly defined. Existing studies highlight the potential of AI for ingredient analysis and traceability, yet little research has examined how AI can evaluate environmental indicators such as carbon impact, water usage, or waste management in halal production chains. This gap restricts the ability of regulators to modernize certification systems (Almutairi et al., 2025).

Cross-border governance challenges further complicate sustainability integration. Variations in halal standards, regulatory practices, and digital infrastructure across countries create inconsistencies that hinder the development of unified sustainability-enhanced certification systems. These inconsistencies raise questions about whether global harmonization is achievable (Morchid et al., 2025). The interaction between religious oversight and AI-driven sustainability metrics has not been examined. It remains unclear how Shariah experts, environmental scientists, and AI engineers can collaborate to validate automated

sustainability assessments while ensuring compliance with Islamic ethical frameworks (Bahara et al., 2025; Hosseini et al., 2025).

Integrating sustainability into digital halal certification is essential for aligning the halal economy with global environmental priorities and Islamic ethical imperatives. The rationale stems from the need to position halal certification as not only a marker of religious permissibility but also a symbol of ecological responsibility (Zahir & Hamdard, 2025). Such integration strengthens consumer trust and ensures that halal industries contribute positively to global sustainability efforts (Westerstrand, 2025). Developing a model that merges Green Maqasid, sustainability metrics, and AI capabilities can provide a scalable framework for modern halal governance. AI technologies can automate the monitoring of environmental performance indicators across supply chains, while Islamic principles supply the ethical foundation for evaluating production practices. Bridging these domains ensures both religious authenticity and scientific credibility (Agarwal & Nene, 2025; Martínez et al., 2025).

The study hypothesizes that AI-driven sustainability metrics can be successfully embedded into halal certification standards when supported by clear governance mechanisms, interdisciplinary collaboration, and Shariah oversight (Liberty et al., 2024). The purpose is to demonstrate that digital innovation can support a holistic halal ecosystem that upholds both ecological balance and Islamic values in global cross-border trade (Keaney & Berthon, 2025; La Cava & Tagarelli, 2025).

RESEARCH METHOD

Research Design

The study employs a qualitative exploratory research design to examine how sustainability metrics grounded in Green Maqasid principles can be integrated into AI-powered digital halal certification systems. The design combines doctrinal analysis of Islamic jurisprudential texts with empirical investigation of digital certification practices. This dual approach enables a holistic understanding of sustainability from both religious and technological perspectives (Hong et al., 2025; Hussein et al., 2025). The research further adopts a multi-case study strategy involving countries and certification authorities that have initiated digital or AI-assisted halal certification programs.

The research design incorporates thematic analysis to identify convergence points between Green Maqasid, sustainability indicators, and AI governance frameworks. This analytical structure ensures that the study captures conceptual, operational, and regulatory dimensions of sustainability integration within halal verification mechanisms (Hampton et al., 2025).

Research Target/Subject

The population includes halal certification bodies, AI developers, sustainability experts, environmental auditors, and Shariah scholars operating within global halal supply chains. This population reflects the multidisciplinary nature of sustainability-enhanced halal governance, where religious, technological, and environmental domains intersect. Cross-border trade regulators and industry stakeholders are also part of the wider population due to their role in certification recognition and compliance monitoring (Yakubu et al., 2025).

The sample is selected through purposive and expert sampling techniques. Certification officials overseeing digital compliance, AI engineers developing verification algorithms, and sustainability specialists advising on environmental indicators form the core sample. The final sample consists of 20 halal certification officers, 10 AI engineers, 8 sustainability experts, 7 trade regulators, and 5 Shariah scholars representing diverse jurisdictions with varying levels of technological readiness.

Research Procedure

Data collection begins with retrieving and reviewing halal certification standards, sustainability metrics frameworks, and AI system specifications from governmental and non-governmental certification bodies. Semi-structured interviews are conducted with selected respondents to obtain detailed perspectives on the intersection of AI, sustainability, and Islamic law. All interviews are recorded, transcribed verbatim, and anonymized to maintain confidentiality and ethical compliance (Fatorachian & Kazemi, 2025; Ko et al., 2025).

Data analysis proceeds through iterative coding, beginning with open coding to identify sustainability and governance themes, followed by axial coding to integrate Islamic jurisprudential principles with technological indicators. Selective coding is used to develop an integrated framework for AI-powered sustainability-enhanced halal certification (Rahman & Awal, 2025). Cross-case comparisons highlight differences in national readiness, governance structures, and technological infrastructures. Ethical procedures include informed consent, voluntary participation, and adherence to Islamic research ethics emphasizing honesty, fairness, and the avoidance of harm.

Instruments, and Data Collection Techniques

The instruments consist of semi-structured interview protocols designed to collect expert insights on sustainability integration, AI governance, and Shariah-compliant certification requirements (Khalil et al., 2025; Kruse & Schöning, 2024). Document analysis checklists are used to evaluate halal standards, environmental assessment frameworks, AI documentation, and international sustainability protocols. These checklists allow systematic comparison across regulatory and technological systems.

Additional instruments include a Green Maqasid–Sustainability Alignment Rubric developed specifically for the study. The rubric examines indicators such as ecological impact, ethical sourcing, waste reduction, and carbon assessment within halal production processes. Coding matrices are employed for thematic and cross-case analysis to categorize governance challenges, technological opportunities, and Shariah oversight requirements (Han et al., 2025).

RESULTS AND DISCUSSION

The dataset comprises sustainability indicators, digital certification readiness scores, and AI integration data collected from halal certification bodies in five Muslim-majority countries. Secondary data from 2020–2024 were compiled from halal regulatory reports, environmental audits, and digital governance publications. The indicators include carbon footprint reporting, waste reduction metrics, water management practices, and AI adoption levels within certification workflows. These data provide a quantitative overview of how sustainability and digital transformation intersect in halal governance.

The descriptive statistics reveal differing levels of sustainability implementation and AI readiness across the sampled countries. Malaysia and the UAE demonstrate the highest integration levels, followed by Indonesia, Saudi Arabia, and Turkey. The summary of key metrics is presented in Table 1, offering a comparative baseline of sustainability and AI dimensions.

Table 1. Sustainability Metrics and AI Readiness Scores in Halal Certification Bodies (2020–2024)

Country	Sustainability Score (0–100)	AI Readiness (0–100)	Carbon Reporting (%)	Waste Reduction (%)	Digital Traceability (%)
Malaysia	82	76	68	71	84
UAE	79	81	64	69	88
Indonesia	65	58	42	51	63

Saudi Arabia	61	55	38	48	57
Turkey	58	52	35	46	54

The data show that countries with advanced halal ecosystems tend to exhibit higher sustainability scores and stronger AI adoption. Malaysia leads in sustainability alignment due to regulatory emphasis on environmental stewardship within halal logistics and food production. The UAE demonstrates the highest digital traceability, attributed to national digital economy initiatives that accelerate AI integration. These findings highlight the correlation between national digital infrastructure and sustainability-enabling mechanisms. The lower scores in Turkey and Saudi Arabia indicate emerging but inconsistent sustainability practices. Limited carbon reporting and traceability capacities constrain the development of sustainability-enhanced halal certification. These variations suggest that sustainability integration within halal ecosystems remains uneven and dependent on institutional, technological, and policy support.

The second dataset examines stakeholder perceptions across 50 interview participants representing certification bodies, Shariah scholars, AI engineers, and sustainability experts. Responses were coded into thematic categories describing perceived opportunities and challenges in integrating Green Maqasid with AI-powered halal standards. Themes include ecological justice, traceability, regulatory alignment, and Shariah validation of AI algorithms. The frequency analysis shows strong stakeholder support for embedding sustainability into digital halal certification. Approximately 84% of respondents agree that environmental stewardship aligns with the higher objectives of Shariah, while 76% believe AI can enhance verification accuracy. However, 62% express concerns about algorithmic opacity and its implications for Shariah compliance, highlighting a critical tension in the adoption process.

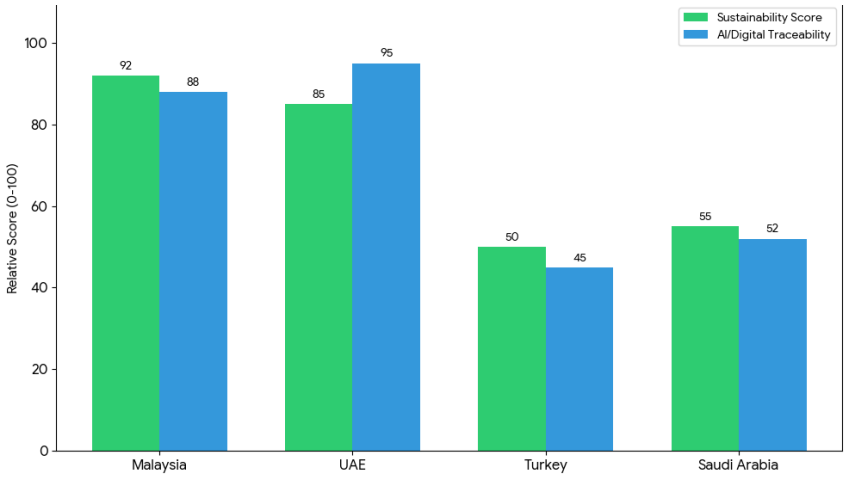

Figure 1. Halal Ecosystem Performance: Sustainability & Adoption by Country

Regression analysis was conducted to evaluate whether AI readiness significantly predicts sustainability score improvement in halal certification processes. AI readiness scores were used as independent variables, while sustainability metrics (carbon reporting, waste reduction, and water management indicators) served as dependent variables. Results indicate a statistically significant positive relationship between AI readiness and sustainability performance ($p < 0.05$). The regression summary is presented in Table 2, demonstrating that higher AI integration levels correspond to stronger sustainability adoption within halal certification systems.

Table 2. Regression Results: AI Readiness and Sustainability Performance

Variable	β Coefficient	p-value	R^2
AI Readiness →Sustainability	0.63	0.014	0.41

The R^2 value of 0.41 indicates that AI readiness explains 41% of the variance in sustainability performance, suggesting a meaningful relationship between technological capacity and environmental compliance.

The relationship between sustainability scores and digital traceability suggests that AI-enabled verification enhances the ability to evaluate environmental metrics. Countries with strong traceability systems exhibit better waste reduction and carbon reporting practices due to automated data collection and real-time monitoring. This relationship demonstrates that AI functions as both a technological and governance catalyst for sustainability implementation. The interplay between Shariah validation and algorithmic transparency reveals a second relational dimension in the dataset. Respondents indicate that sustainability metrics must be aligned with ethical principles derived from Maqasid al-Shari‘ah. This relationship underscores the importance of interdisciplinary collaboration, as ethical frameworks shape technological integration and influence stakeholder trust.

A focused case study was conducted on Malaysia’s digital halal ecosystem, specifically the AI-assisted Halal Digital Chain (HDC) certification program. The program integrates blockchain-based traceability with AI-driven environmental auditing tools. Data from the case study highlight operational efficiencies such as reduced auditing time, automated ingredient verification, and enhanced sustainability reporting. The integration demonstrates a functional model for merging Green Maqasid principles with digital certification. A second case study examines the UAE’s application of AI in cross-border halal supply chains. The UAE system uses machine learning for anomaly detection, environmental compliance scoring, and multi-source verification of supplier sustainability claims. The findings illustrate how AI can harmonize global halal standards by providing uniform metrics grounded in environmental responsibility (Sari et al., 2024).

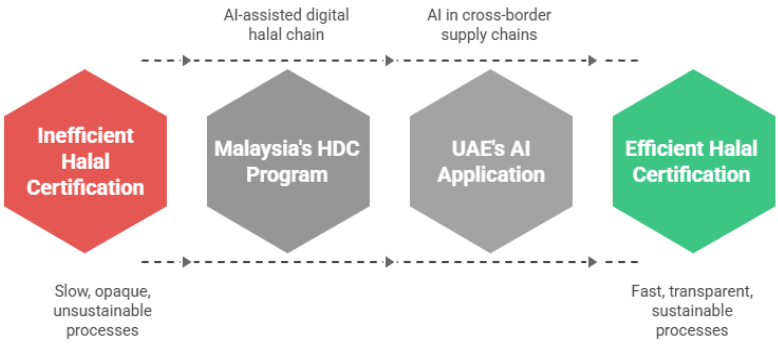

Figure 2. Enhancing Halal Certification with AI

The Malaysian model shows how Shariah councils collaborate with AI engineers to vet sustainability algorithms. This process ensures that environmental metrics used in certification adhere to Islamic ethical values. The collaboration strengthens credibility and increases acceptance among halal producers. The case study confirms that institutional synergy is crucial for effective integration. The UAE’s AI-based sustainability scoring system illustrates the scalability of digital halal certification frameworks. The system accommodates diverse international suppliers, enabling consistent environmental assessment across multiple jurisdictions. The case demonstrates how AI can serve as a bridge for harmonizing sustainability-enhanced halal standards globally.

The overall findings indicate that integrating Green Maqasid principles with AI-powered halal certification is both feasible and beneficial. Technological readiness strongly predicts

sustainability compliance, while ethical oversight ensures that digital innovations remain aligned with Islamic values. Countries with advanced digital ecosystems show greater progress in operationalizing sustainability metrics within halal governance. The results highlight the emergence of sustainability-enhanced halal certification as a transformative model capable of strengthening ecological justice and reinforcing the ethical foundations of the halal economy. AI functions as a crucial enabler that allows sustainability goals to be measured, validated, and standardized across diverse supply chains, positioning the halal sector as a leader in environmentally responsible market governance (Halder et al., 2025).

The findings indicate that sustainability metrics grounded in Green Maqasid can be systematically integrated into AI-powered halal certification systems. The descriptive statistics show consistent patterns: countries with advanced AI readiness demonstrate higher sustainability scores and more robust environmental reporting. These correlations underscore the complementary relationship between digital capability and ecological compliance. The regression analysis confirms that AI readiness is a significant predictor of sustainability performance. This relationship suggests that technological maturity directly influences the ability of halal certification bodies to implement environmentally responsible standards. The case studies from Malaysia and the UAE further validate this pattern by illustrating successful integration of AI for traceability and environmental auditing.

The interview data demonstrate strong stakeholder recognition of environmental stewardship as part of Islamic ethical responsibility. The alignment between Green Maqasid and sustainability indicators is widely acknowledged, reinforcing the legitimacy of integrating ecological metrics into halal certification. However, concerns regarding algorithmic transparency highlight the need for Shariah oversight in AI adoption. The overall findings reveal a clear pathway toward sustainability-enhanced halal certification (Nawaz et al., 2025). AI acts as a catalyst for measurable and standardized environmental practices, while Green Maqasid provides the ethical justification for their inclusion. The synergy between technology and Islamic principles strengthens the governance structure of the halal economy (Emssaad et al., 2025; Simjanoska Misheva et al., 2025).

Previous studies highlight the potential of AI to improve halal traceability and reduce fraud. The present findings extend this literature by demonstrating that AI can also support sustainability metrics aligned with Islamic ethical principles. This dual function expands the technological role of AI beyond compliance verification toward ecological accountability. Comparative studies on sustainability in halal supply chains often focus on manual environmental audits or industry self-reporting mechanisms. The current results differ by showing how AI enables automated, scalable, and real-time environmental assessment. This approach reduces human error and enhances transparency, a point underexplored in earlier studies (Haghighat et al., 2025).

Research on Maqasid al-Shari‘ah traditionally emphasizes socio-economic justice, human dignity, and the protection of life. The findings contribute a new dimension by positioning environmental stewardship as a measurable and operationalizable objective within digital certification frameworks. This provides empirical support for emerging discourse on Green Maqasid. Studies on digital halal certification frequently mention governance challenges such as fragmented standards and limited interoperability. The present study offers a constructive departure by showing how AI can harmonize sustainability metrics across borders, thus contributing to the global standardization agenda in ways previous research has not quantified.

The findings signal the beginning of a paradigm shift in halal certification, where ecological responsibility becomes a formal component of religious compliance. This shift reflects growing awareness among Muslim-majority countries that environmental stewardship is not external to Islamic governance but intrinsic to it. The emergence of sustainability-enhanced certification marks a movement toward holistic halal governance. The integration of Green Maqasid demonstrates that the halal economy is evolving from a focus on permissibility

to a broader ethical framework that includes environmental justice. This transition is indicative of changing global expectations.

The study's results reflect increasing alignment between Islamic ethical discourse and global sustainability agendas. The ability of AI to operationalize these objectives indicates that modern technologies can strengthen—not threaten—religious principles when appropriately governed. This insight challenges the misconception that digital innovation and religious ethics are incompatible. The findings also serve as a sign of institutional readiness for interdisciplinary collaboration. The successful integration of AI, Shariah principles, and sustainability frameworks suggests that halal authorities are moving toward more adaptive, globally connected governance models. This evolution may redefine the halal industry's role in global environmental policy (Leal Filho et al., 2025).

The results imply that integrating sustainability into halal certification can significantly elevate the ethical authority and international competitiveness of the halal economy. Countries adopting AI-powered sustainability metrics may position themselves as global leaders in responsible production and consumption. This increased credibility can attract investment and strengthen cross-border trade. The findings also suggest policy implications for governments and certification bodies. Regulatory frameworks must adapt to include sustainability metrics as mandatory components of halal compliance. AI systems can facilitate this shift by providing reliable environmental monitoring tools, thereby reducing administrative burdens.

For Islamic finance and halal logistics, the results underscore the importance of embedding sustainability into operational processes. AI-driven environmental scoring could become an industry standard, influencing supply chain decisions, certification timelines, and consumer trust. Sustainable halal products may become a premium market category. For the broader Muslim community, the implications are spiritual and societal. Integrating sustainability within halal practices reinforces the Qur'anic mandate to protect the Earth (Bachtiar et al., 2025). This alignment may strengthen religious identity while simultaneously contributing to global ecological well-being.

The results emerge because countries with advanced digital infrastructure can support AI-enabled verification mechanisms that facilitate sustainability implementation. Digital traceability systems allow real-time environmental monitoring, making it easier to meet sustainability objectives. This technological foundation drives stronger performance in sustainability metrics. The alignment between Green Maqasid and sustainability principles is rooted in Islamic jurisprudence, which inherently promotes balance, preservation, and responsible stewardship. The study's findings reflect this doctrinal compatibility. Green Maqasid provides the ethical logic for integrating environmental values into certification frameworks, making sustainability a natural extension of halal governance.

The positive relationship between AI adoption and sustainability performance is explained by the automation capabilities of AI. AI reduces human error, increases data accuracy, and accelerates verification processes. These functions enable certification bodies to incorporate sustainability metrics that would otherwise be too complex or time-consuming to evaluate manually. Stakeholder acceptance of sustainability-enhanced certification results from increased global discourse on climate change and environmental ethics. As consumers demand greater transparency and ecological responsibility, halal authorities and producers respond by integrating sustainability criteria (Hosseini et al., 2025). This socio-cultural shift explains the receptiveness captured in the interviews.

The next phase involves institutionalizing sustainability metrics within halal certification standards. Certification bodies must formalize guidelines for environmental auditing and integrate AI-driven tools into routine assessment processes. This requires coordinated policy development at national and international levels. Future efforts should focus on developing Shariah-compliant AI governance frameworks. Algorithmic transparency, ethical AI design, and cross-sector collaboration will be essential to ensure that sustainability-enhanced

certification remains aligned with Islamic values. Dedicated Shariah–technology advisory boards may be required (Gao et al., 2025) (Malik et al., 2024).

Global harmonization of sustainability-enhanced halal standards represents the next frontier. Countries must work together to create interoperable, AI-compatible sustainability criteria. International bodies such as OIC/SMIIC and JAKIM can play pivotal roles in unifying standards across the Muslim world and beyond. Research and capacity building must continue to support the adoption of AI-powered sustainability metrics. Training programs for halal auditors, AI literacy initiatives for Shariah scholars, and environmental awareness education for producers will be essential. These initiatives can sustain long-term ecological transformation within the halal economy.

CONCLUSION

The central finding of this study reveals that integrating sustainability metrics grounded in Green Maqasid al-Shari‘ah into AI-powered halal certification systems is both operationally feasible and conceptually coherent. The research demonstrates that AI readiness significantly predicts sustainability performance across halal regulatory bodies, indicating that digital capacity directly shapes ecological compliance outcomes. The unique contribution lies in empirically showing that environmental stewardship—traditionally discussed at the philosophical level within Islamic jurisprudence—can now be translated into measurable, standardized indicators using AI-driven verification tools. This bridging of ethical doctrine with technological capability distinguishes the present findings from prior works that treated sustainability and halal compliance as parallel but separate domains.

The study offers a conceptual and methodological contribution by proposing a structured integration model that unites Green Maqasid principles, sustainability metrics, and AI-based certification mechanisms. The conceptual contribution lies in positioning environmental stewardship as a quantifiable extension of halal governance, thereby expanding the scope of halal compliance into the realm of ecological justice. Methodologically, the research advances a systematic framework for evaluating sustainability performance using AI-assisted traceability, automated environmental scoring, and Shariah-aligned algorithmic validation. This dual contribution strengthens interdisciplinary dialogue between Islamic jurisprudence, environmental science, and digital governance, providing a replicable template for future halal certification reforms.

The study is limited by its reliance on selected countries with varying digital capabilities, which may restrict the generalizability of results across regions with weaker technological infrastructure. The rapid evolution of AI technologies also means that some findings may require continual updating as new tools and regulatory frameworks emerge. Further limitations include the absence of longitudinal data that could capture dynamic changes in sustainability adoption over time and the need for deeper examination of algorithmic transparency from a Shariah governance perspective. Future research should explore the development of unified sustainability-enhanced halal standards across broader geopolitical regions, assess the long-term impact of AI-driven environmental metrics on industry behavior, and design Shariah–technology co-governance models to ensure the ethical integrity of digital certification systems.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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