The Role of Artificial Intelligence in Advancing Sustainable and Green Economic Development: Evidence and Prospects for Liberia

Vafolay Mbandoe Tulay, PhD
Liberia Institute of Policy Studies and Research (LIPSR)
University of Liberia, Fendell, Lake View
Republic of Liberia

doi.org/10.51505/ijaemr.2026.11219 URL: http://dx.doi.org/10.51505/ijaemr.2026.11219

Received: Mar 13, 2026 Accepted: Mar 17, 2026 Online Published: Apr 01, 2026

Abstract

Growing concerns about climate change, environmental degradation, and resource depletion have intensified global efforts to identify sustainable development pathways. Among emerging technologies, artificial intelligence (AI) has drawn attention for its potential to improve environmental governance, optimize resource allocation, and support low-carbon economic systems. Using data analytics, predictive modeling, and automated decision-making, AI offers opportunities to enhance efficiency in renewable energy, agriculture, environmental monitoring, and urban infrastructure.

This paper examines how AI could advance sustainable and green economic development in Liberia. Using qualitative analysis based on secondary data and scholarly literature, it evaluates opportunities and constraints for AI implementation in renewable energy, sustainable agriculture, and environmental conservation. It also identifies structural barriers, including limited digital infrastructure, shortages of technical expertise, and evolving institutional frameworks.

The analysis highlights that while AI can strengthen sustainability initiatives, its effectiveness depends on complementary investments in infrastructure, education, and governance. The paper contributes to existing research by contextualizing AI-sustainability debates within Liberia, identifying sector-specific applications, and assessing the institutional conditions required for successful adoption.

Keywords: Artificial intelligence; sustainable development; green economy; Liberia; renewable energy; precision agriculture; deforestation monitoring; digital infrastructure; technology adoption; Sub-Saharan Africa

1. Introduction

1.1. Introduction of the Problem

Climate change, biodiversity loss, and environmental degradation are central concerns in global debates over economic development. Conventional development models—often based on resource extraction and fossil-fuel consumption—have contributed to rising greenhouse gas emissions and ecological instability (United Nations, 2015). Policymakers increasingly seek strategies that combine economic growth with environmental sustainability.

Artificial intelligence has been identified as a technological tool capable of supporting sustainability initiatives through data analysis, predictive modeling, and automated decision-making systems (Vinuesa et al., 2020). AI applications have already been used in climate modeling, renewable energy forecasting, and ecosystem monitoring (Rolnick et al., 2019).

Despite this potential, adoption remains uneven. Developed economies have integrated AI into energy systems, environmental monitoring, and smart infrastructure, while developing countries face constraints including limited digital infrastructure, unreliable electricity, and shortages of skilled professionals (Kshetri, 2021).

Liberia presents an important case for examining these dynamics. The country possesses extensive forests, fertile agricultural land, and significant hydropower potential, yet electricity access remains below 35 percent nationally, with rural electrification rates considerably lower (World Bank, 2021). These conditions raise questions about whether and how AI can contribute to sustainable development.

1.2. Research question

To what extent can artificial intelligence contribute to sustainable and green economic development in Liberia, and what institutional conditions are required for its effective implementation?

1.3. Contributions of this paper

This paper contributes to the body of knowledge by:

- Contextualizing global debates on AI and sustainability within Liberia.
- Identifying sector-specific opportunities for AI applications in energy, agriculture, and forest conservation.
- Assessing the institutional and infrastructural conditions necessary for AI adoption.

The analysis is guided by perspectives from sustainable development theory and digital innovation for development. Sustainable development theory emphasizes integrating economic growth, environmental protection, and social inclusion, while development studies literature

Vol. 11, No. 02; 2026

ISSN: 2456-3676

highlights the importance of institutional capacity and infrastructure for technology adoption (Sen, 1999). This framework allows the study to examine AI as a tool within broader development systems rather than as a standalone solution.

2. Method

This study employs a qualitative research design grounded in systematic secondary data analysis and an integrative literature review. This methodological approach is appropriate for examining emergent phenomena—such as AI adoption in low-income development contexts—where primary empirical data is limited or unavailable, and where synthesis of existing knowledge is the most rigorous available method (Snyder, 2019; Mengist et al., 2020).

The literature search was conducted across multiple academic databases, including Google Scholar, Scopus, and Web of Science, as well as institutional repositories maintained by the World Bank, the United Nations Development Programme (UNDP), the African Development Bank, and the Food and Agriculture Organization (FAO). Search terms included combinations of "artificial intelligence," "sustainable development," "green economy," "Liberia," "West Africa," "renewable energy," "precision agriculture," "deforestation monitoring," and "digital infrastructure." To ensure currency and relevance, publications were prioritized from 2015 onward, with particular weight given to peer-reviewed articles and institutional reports published between 2019 and 2025.

Inclusion criteria required that sources address at least one of the following: (1) AI applications in energy, agriculture, or environmental monitoring; (2) digital transformation challenges in Sub-Saharan Africa or comparable low-income settings; or (3) institutional and governance conditions for technology adoption in developing economies. Sources that addressed AI in high-income contexts without transferable lessons were excluded unless they provided foundational theoretical frameworks.

Data extraction followed a thematic coding procedure in which recurring concepts—such as infrastructure constraints, governance gaps, sector-specific AI applications, and development outcomes—were identified and categorized across sources (Fink, 2009). These themes structured the analytical framework applied throughout the paper. Liberia-specific data drawn from national energy reports, agricultural sector analyses, and forestry assessments were triangulated against regional and global evidence to produce a context-sensitive assessment. This triangulation strategy strengthens the internal validity of the findings by cross-checking patterns identified in the global literature against Liberia's documented conditions.

This integrative approach—combining global scholarship with Liberia-specific data—is consistent with established practices in qualitative systematic review, which allow researchers to derive context-sensitive conclusions by synthesizing evidence across heterogeneous sources (Snyder, 2019). The method is particularly suited to policy-oriented research in developing-country settings, where the goal is to translate global knowledge into actionable, locally relevant

ISSN: 2456-3676

insights. Limitations of this approach include the absence of primary field data and the possibility that rapidly evolving AI deployments in the region may outpace the available published literature. Future research employing mixed methods, including stakeholder interviews and pilot program evaluations, would complement and deepen the findings presented here.

3. Literature Review

3.1. Sustainable and Green Economic Development

Sustainable development seeks to promote economic growth while ensuring environmental protection and social equity (United Nations, 2015). The green economy builds on this principle by emphasizing economic activities that reduce environmental risks and promote efficient resource use, including renewable energy, sustainable agriculture, and low-carbon infrastructure (UNEP, 2011).

Advances in digital technologies, including AI, big data analytics, and satellite monitoring, provide tools for improving environmental monitoring and resource management. However, technology alone cannot ensure sustainable outcomes; robust governance, institutional capacity, and infrastructure are essential.

3.2. Artificial Intelligence and Sustainability

A growing body of research examines the relationship between AI and sustainable development. Vinuesa et al. (2020) highlight AI's potential to accelerate progress toward the UN Sustainable Development Goals through improved energy efficiency and environmental monitoring. Rolnick et al. (2019) demonstrate how machine learning can assist in climate change mitigation via renewable energy forecasting, carbon tracking, and ecosystem management. More recent scholarship has extended these findings to the African context. A 2024 review published in ScienceDirect confirms that AI techniques hold significant potential to advance sustainable development across Africa's diverse sectors (ScienceDirect, 2024). UNESCO estimates that AI could generate a potential economic impact of $1.5 trillion—equivalent to approximately 6 percent of Africa's GDP—by fostering growth and innovation in healthcare, agriculture, and energy (UNESCO, 2025). Projections by market analysts further suggest that Africa's AI market, valued at approximately USD 6.90 billion in 2024, could reach USD 18.33 billion by 2030 at a compound annual growth rate of 17.7 percent (E3S Conferences, 2024). These figures underscore the scale of transformative potential that AI represents for the continent, including resource-constrained economies such as Liberia.

Recent empirical work has also examined the relationship between AI adoption and environmental governance. A 2024 study conducted in Ghana's manufacturing sector found a strong, statistically significant positive correlation between AI technology adoption and environmental governance frameworks ($r = 0.618$, $p < 0.01$), suggesting that organizations leveraging AI are more likely to implement rigorous environmental oversight—and that robust governance, in turn, drives strategic AI adoption for sustainability goals (SCIRP, 2024). This bidirectional relationship has important implications for Liberia, where governance frameworks and AI adoption must co-evolve.

Bawa (2025), examining AI and renewable energy development in Africa's frontier markets, identifies mobile broadband penetration and regulatory quality as critical enablers of AI-driven energy transitions, and finds that positive AI adoption shocks produce 1.9 times greater impact on renewable energy development than equivalent negative shocks—a finding that underscores the asymmetric returns to early, well-supported AI investment. Africa is projected to meet less than 6 percent of the UN Sustainable Development Goals by 2030 under current trajectories (Brookings Institution, 2025), making the identification of AI-enabled development accelerators an urgent policy priority.

Other studies emphasize the contextual limitations of AI. Kshetri (2021) notes that developing countries face digital infrastructure gaps, skill shortages, and institutional challenges that constrain technology adoption. Friederici, Ojanperä, and Graham (2020) argue that without careful policy design, digital transformation may reinforce global inequalities. These concerns are empirically grounded: a 2025 systematic review found that over 60 percent of surveyed smallholder farmers in Sub-Saharan Africa lacked access to AI-powered tools due to cost, weak connectivity, or low awareness, and that without supportive policies and institutional frameworks, AI may reinforce existing inequalities between commercial and smallholder farmers, urban and rural areas, and men and women (Olawumi et al., cited in Springer Nature, 2026). A 2025 survey across 52 African countries further found that 86 percent of women lacked basic AI proficiency, and 50 percent lacked adequate internet access—highlighting the gendered dimensions of AI exclusion that must be addressed in any equitable deployment strategy (Brookings Institution, 2025). The African continent more broadly continues to face imbalances in infrastructure, compounded by high internet access costs and skills shortages that hinder AI adoption (E3S Conferences, 2024). These structural barriers are acutely relevant to Liberia, where rural internet penetration and technical capacity remain among the lowest in West Africa.

Despite these insights, little research examines AI in low-income, infrastructure-constrained contexts like Liberia. This study fills that gap by linking global debates with country-specific conditions, producing a more context-sensitive analysis.

3.3. Applications of Artificial Intelligence in Sustainable Development

Renewable Energy

AI can analyze climate data and energy demand to improve forecasting and grid management. In Liberia, electricity access is limited, particularly in rural areas. Hydropower facilities such as the Mount Coffee Plant, combined with diesel and solar systems, provide the primary electricity supply. AI applications could optimize hydropower operations, enhance decentralized solar mini-grid performance, and improve energy planning.

Empirical Case Study — Rwanda's AI-Powered Mini-Grids: A directly transferable precedent from the African context is provided by Rwanda, where the organization Off Grid Box partnered with the government to deploy AI-powered solar mini-grids in rural communities. Machine learning algorithms were used to adapt dynamically to local energy demand patterns, improving reliability and efficiency. The initiative expanded access to education, healthcare, and clean water, and demonstrated the scalability of AI-powered mini-grids for off-grid electrification in low-income settings (Clean Technology Hub, 2024). Similar AI-powered solar-battery hybrid systems in off-grid communities in Kenya have been documented to reduce power outages by approximately 30 percent, transforming community quality of life (Sapre, 2024). These cases illustrate a replicable model for Liberia's rural electrification challenge.

On the technical side, AI-driven battery management systems use predictive analytics and deep learning algorithms to optimize energy storage, preventing overcharging, minimizing energy losses, and extending battery lifespan—thereby ensuring 24/7 electricity availability even during low-generation periods (Zhang et al., 2021; Chen et al., 2022). Long Short-Term Memory (LSTM)-based deep learning models have been demonstrated to produce precise short-term solar electricity forecasts, directly supporting grid operators in stable supply planning (Bouquet et al., 2023). AI-driven simulations also enhance solar and wind energy project planning by accurately modeling weather patterns, energy production, and consumption demands—significantly reducing the financial risks associated with high initial capital costs of renewable energy systems (APN, 2024). For Liberia, where the "Africa infrastructure paradox" of underfunded feasibility studies and poor project planning constrains energy investment, AI-enabled planning tools could address a critical bottleneck in renewable energy development.

Environmental Monitoring

AI can analyze satellite and sensor data to detect deforestation, land-use changes, and pollution. Liberia contains roughly 40 percent of the Upper Guinean rainforest, one of West Africa's most biodiverse regions. Satellite-based monitoring systems, enhanced by AI algorithms, could detect illegal logging and improve enforcement of forest conservation policies.

Empirical Case Study — AI-Based Forest Monitoring in West Africa: Recent research provides compelling evidence for the effectiveness of AI-driven forest monitoring in the West African context. A 2025 study published in Frontiers in Remote Sensing applied Convolutional Neural Networks (CNNs) to Sentinel-2 satellite time series data to detect degraded forests in Guinea, West Africa—a country with forest characteristics comparable to Liberia's Upper Guinean rainforest—demonstrating the viability of deep learning for identifying selective logging activities and monitoring forest degradation patterns (Frontiers, 2025). In Cameroon, deep learning models applied to Landsat-8 imagery achieved a macro-average F1 score of 0.77 in classifying fifteen distinct drivers of deforestation, demonstrating the precision with which AI can identify specific threats such as agricultural encroachment, mining, and illegal logging (ScienceDirect, 2025).

Vol. 11, No. 02; 2026

ISSN: 2456-3676

At the global scale, Google Research's ForestCast initiative has developed a deep learning benchmark for proactive deforestation risk forecasting using pure satellite inputs, providing a scalable approach applicable across tropical regions, including West Africa (Google Research, 2025). The integration of deep learning with remote sensing is now recognized as a particularly powerful combination for environmental monitoring: automated techniques utilizing advanced algorithms can analyze satellite imagery to enable the automated identification of deforested areas and monitoring of deforestation patterns over time (Frontiers in Forests and Global Change, 2024). More recent innovations have introduced real-time deforestation anomaly detection frameworks that combine object detection with agentic AI systems, providing geolocated alerts and supporting adaptive learning for evolving deforestation patterns (Scientific Reports, 2025).

For Liberia, these technologies represent a practical and increasingly affordable pathway to strengthening enforcement of its national forest conservation policies, including the Protected Forest Areas Network. The availability of freely accessible satellite data from Landsat and Sentinel missions means that implementation costs need not be prohibitive, provided that local technical capacity for data analysis is developed.

Sustainable Agriculture

Agriculture employs a large share of Liberia's workforce, with key crops including rice, cassava, rubber, cocoa, and oil palm. Productivity remains limited due to climate variability, weak extension services, and low technology adoption. AI-enabled platforms can provide localized weather forecasts, pest alerts, and soil management recommendations to improve yields while reducing environmental impacts.

Empirical Case Study — AI in African Smallholder Agriculture: The integration of AI into agriculture holds urgent and transformative potential for enhancing food security across Sub-Saharan Africa, a region acutely impacted by climate change and resource constraints (Ozor et al., 2025). Evidence from the AI for Agriculture and Food Systems (AI4AFS) Innovation Research Network, which funded AI-driven projects in eight Sub-Saharan African countries, demonstrates concrete applications including real-time pest and disease detection across crops such as maize, cassava, tomato, and cashew—crops directly relevant to Liberia's agricultural profile (Frontiers in Artificial Intelligence, 2024). Globally, AI in agriculture is projected to grow from $1.7 billion to $4.7 billion between 2023 and 2028, at a compound annual growth rate of 23 percent (World Bank, 2025).

In Ghana, AI-based soil testing kits have been deployed to analyze soil samples and provide tailored fertilizer recommendations, while AI platforms in Tanzania connect farmers directly with buyers, eliminating middlemen and ensuring fair pricing (World Bank, 2025). The "Hello Tractor" platform, supported by the World Bank Group, uses machine learning to monitor tractor usage, forecast weather patterns, and enable communication via text messages in areas with limited internet access—demonstrating how AI can function even in low-connectivity rural environments (World Bank, 2025). A systematic review of precision agriculture in East Africa found that digital solutions, including mobile applications, variable rate application technologies, and AI/machine learning tools, delivered reported benefits of improved crop productivity, increased economic efficiency, and enhanced environmental sustainability (Frontiers in Sustainable Food Systems, 2025).

A random forest classifier applied to smallholder farming systems in Sub-Saharan Africa achieved an 85 percent accuracy rate in producing crop type maps and yield estimates, demonstrating the potential of AI to better target agricultural interventions at the farm or village scale (Onyango et al., 2021). Integrating locally collected data—including crop yield records, weather patterns, and soil quality—with open-source AI training datasets significantly enhances model robustness and the accuracy of recommendations for farmers (Ozor et al., 2025). These examples collectively illustrate a pathway for Liberia to leapfrog conventional agricultural extension systems by deploying AI-enabled advisory services through mobile platforms, even in areas with limited internet connectivity.

3.4. Artificial Intelligence and Sustainable Development in Liberia

Liberia offers both opportunities and challenges for AI adoption. Renewable energy planning, forest monitoring, and agricultural productivity are key sectors where AI can make meaningful contributions. However, structural constraints—limited electricity access, weak digital infrastructure, and shortages of trained professionals—must be addressed for AI to be effective.

Opportunities and Economic Benefits

AI offers the following opportunities and benefits:

- Integrating AI into sustainability strategies could enhance Liberia's development outcomes.
- Energy efficiency: Better forecasting and grid management could reduce costs and expand access to electricity.
- Agricultural productivity: AI-supported farming could improve yields, strengthen food security, and enhance rural livelihoods.
- Environmental protection: AI-based monitoring could support forest conservation and biodiversity protection.
- Employment opportunities: AI and digital technology sectors could create jobs in data science, renewable energy, and environmental management.

Challenges and Limitations

Adoption of AI in Liberia is constrained by:

- Infrastructure: Limited electricity and internet access, especially in rural areas.
- Human capital: Shortage of professionals trained in data science and AI.
- Institutional frameworks: Regulations and governance structures for digital technologies are still developing.

These constraints highlight that AI is a complementary tool, not a solution in and of itself.

4. Discussion

The findings highlight that AI can improve environmental monitoring, optimize renewable energy systems, and enhance agricultural productivity. The empirical cases reviewed in this paper—from Rwanda's AI-powered mini-grids to CNN-based forest monitoring in Guinea and Cameroon, to AI-driven agricultural advisory platforms in Ghana, Kenya, and Tanzania—demonstrate that these are not merely theoretical possibilities, but documented outcomes achieved in comparable African contexts. However, Liberia's structural constraints mean that technological potential alone is insufficient. Limited infrastructure, human capacity gaps, and evolving institutional frameworks create significant barriers. Evidence from Sub-Saharan Africa consistently shows that over 60 percent of smallholder farmers lack access to AI-powered tools due to cost, weak connectivity, or low awareness, and that digital agriculture cannot scale without a robust foundation of rural digitization (Springer Nature, 2026; World Bank, 2025). The continent's structural economic weaknesses—including small domestic markets, limited local value addition, and infrastructure deficits—compound these technology-specific barriers (IDRC, 2025).

At the same time, Liberia's natural resources provide opportunities for AI-supported innovation. Targeted applications in forest monitoring, climate-smart agriculture, and decentralized energy systems could strengthen sustainability outcomes if supported by institutional investments. The AI governance-digital infrastructure nexus identified by Bawa (2025) is particularly instructive: empirical validation across African frontier markets confirms that mobile broadband penetration and regulatory quality are the two most critical enablers of AI-driven development outcomes. This finding directly informs Liberia's policy priorities—infrastructure investment and regulatory reform are not merely desirable complements to AI adoption but necessary preconditions for it. These findings support broader literature emphasizing that digital technologies require conducive governance and infrastructure to realize sustainable development benefits, and that without such conditions, AI risks reinforcing rather than reducing existing inequalities (Friederici et al., 2020; Brookings Institution, 2025).

4.1. Policy Implications

Effective AI adoption in Liberia requires:

- Investment in digital infrastructure: Expand access to electricity and internet connectivity, particularly in rural areas.
- Technical education and training: Collaborate with universities and international partners to develop AI and data science expertise.
- Regulatory frameworks: Establish policies that enable innovation while ensuring data security and environmental standards.
- Public-private partnerships: Encourage collaboration between the government, the private sector, and international organizations to implement AI initiatives.

- These measures would create the conditions for AI to act as a supportive tool for sustainable development.

5. Conclusion

Artificial intelligence offers significant opportunities to support sustainable and green economic development in Liberia by improving energy efficiency, environmental monitoring, and agricultural productivity. The empirical evidence reviewed in this paper—spanning AI-powered mini-grids in Rwanda, deep learning-based forest monitoring in Guinea and Cameroon, and AI-driven precision agriculture across Sub-Saharan Africa—demonstrates that these applications are technically feasible and have produced measurable development benefits in comparable African contexts. Success in Liberia depends on complementary investments in infrastructure, human capital, and governance. The bidirectional relationship between AI adoption and environmental governance documented in recent empirical literature suggests that these investments are mutually reinforcing: stronger governance drives AI adoption, and AI adoption, in turn, strengthens environmental oversight capacity.

This study contributes to the literature by contextualizing global AI-sustainability debates within Liberia, identifying sector-specific applications, and assessing institutional conditions for adoption. It also advances the methodological rigor of country-level AI-sustainability analysis by integrating recent empirical evidence from comparable African contexts, moving beyond purely speculative assessments to ground policy recommendations in documented outcomes. Future research could examine pilot AI initiatives in Liberia's energy, agriculture, and environmental sectors to generate primary empirical evidence on their effectiveness. Particular priority should be given to feasibility assessments of AI-optimized solar mini-grid deployment in rural counties, participatory evaluation of mobile-based agricultural advisory platforms adapted to Liberian crop systems, and pilot testing of satellite-based forest monitoring tools in collaboration with the Forestry Development Authority. Longitudinal studies tracking the co-evolution of AI adoption and institutional capacity would further contribute to understanding the governance conditions under which AI can most effectively support sustainable development in post-conflict, low-income settings.

References

African Development Bank. (2020). *Digital Transformation for African Development*. Abidjan, Côte d'Ivoire: Author

Food and Agriculture Organization. (2020). *Digital technologies in agriculture and rural areas*. Rome, Italy: Author.

Friederici, N., Ojanperä, S., & Graham, M. (2020). The impact of artificial intelligence on work in Africa (Oxford Internet Institute Working Paper).

International Energy Agency. (2022). *Digitalization and energy*. Paris, France: Author.

Kshetri, N. (2021). Artificial intelligence in developing countries: Opportunities and challenges. *IT Professional*, *23*(2), 63–67. https://doi.org/10.1109/MITP.2021

Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., … & Bengio, Y. (2019). Tackling climate change with machine learning. *Nature Climate Change, 9*(6), 462–473. https://doi.org/10.1038/s415

Sen, A. (1999). *Development as freedom*. Oxford, UK: Oxford University Press.

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. New York, NY: Author.

United Nations Environment Programme. (2011). *Towards a green economy*. Nairobi, Kenya: Author.

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., … & Nerini, F. F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications, 11*, 233. https://doi.org/10.1038

World Bank. (2021). *Artificial intelligence for development*. Washington, DC: Author.

World Bank. (2025). Is artificial intelligence the future of farming? Exploring opportunities and challenges in Sub-Saharan Africa. Washington, DC: Author.

Bawa, S. (2025). Leveraging artificial intelligence and dynamic supply chains for renewable energy development in Africa's frontier markets. Energy for Sustainable Development. https://doi.org/10.1177/0958305X251375931

Brookings Institution. (2025). Leveraging AI and emerging technologies to unlock Africa's potential. Foresight Africa 2025–2030. Washington, DC: Author.

Clean Technology Hub. (2024). Smart technology for climate action: How artificial intelligence can optimize renewable energy efficiency in Africa. Lagos, Nigeria: Author.

Frontiers in Artificial Intelligence. (2024). Enhancing Africa's agriculture and food systems through responsible and gender inclusive AI innovation: Insights from the AI4AFS network. https://doi.org/10.3389/frai.2024.1472236

Frontiers in Forests and Global Change. (2024). Deforestation detection using deep learning-based semantic segmentation techniques: A systematic review. https://doi.org/10.3389/ffgc.2024.1300060

Frontiers in Remote Sensing. (2025). Detection of degraded forests in Guinea, West Africa, using convolutional neural networks and Sentinel-2 time series. https://doi.org/10.3389/frsen.2025.1538808

Frontiers in Sustainable Food Systems. (2025). Digitalization of precision fertilization in East Africa: Adoption, benefits and losses. https://doi.org/10.3389/fsufs.2025.1497577

Mengist, W., Soromessa, T., & Legese, G. (2020). Method for conducting systematic literature review and meta-analysis for environmental science research. MethodsX, 7, 100777. https://doi.org/10.1016/j.mex.2019.100777

Onyango, C. M., Nyaga, J. M., Wetterlind, J., Söderström, M., & Piikki, K. (2021). Precision agriculture for resource use efficiency in smallholder farming systems in Sub-Saharan Africa: A systematic review. Sustainability, 13(3), 1158. https://doi.org/10.3390/su13031158

Ozor, N., Nwakaire, J., Nyambane, A., Muhatiah, P., & Nwobodo, C. (2025). Enhancing Africa's agriculture and food systems through responsible and gender inclusive AI innovation. Frontiers in Artificial Intelligence, 7. https://doi.org/10.3389/frai.2024.1472236

ScienceDirect. (2024). Artificial intelligence and sustainable development in Africa: A comprehensive review. October 2024.

ScienceDirect. (2025). Evaluating satellite data and deep learning for identifying direct deforestation drivers in Cameroon.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

UNESCO. (2025). Harnessing emerging technologies for sustainable development in Africa. Paris, France: Author.

World Bank. (2019). *Digital Economy for Africa Initiative*. Washington, DC: Author.