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ARTIFICIAL INTELLIGENCE AND SUSTAINABLE DEVELOPMENT GOALS IN NIGERIA: A CONCEPTUAL REVIEW

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Abstract

Artificial Intelligence (AI) is a rapidly evolving technology that has the potential to revolutionize various sectors globally. In the context of sustainable development, AI plays a pivotal role by offering innovative solutions to some of the most pressing environmental, social, and economic challenges. The integration of AI in sustainable development goals is gaining momentum, particularly in developing countries like Nigeria, where there is a need to balance economic growth with environmental preservation and social equity. The aim of this paper x-rayed the contributions and the potential influence of AI to sustainable development goals in Nigeria, and effects of AI on sustainable development in Nigeria, Challenges and Ethical Considerations. The study is anchored on Machine Learning Theory credited by Arthur Samuel, an American pioneer in the field of computer gaming and artificial intelligence in 1959. The study concluded that integration of AI into

sustainable development initiatives in Nigeria holds great promise. AI can drive innovation in key sectors like agriculture, healthcare, energy, and urban planning, enabling Nigeria to meet its sustainable development goals. However, this potential can only be realized if there is a concerted effort to address the challenges related to infrastructure, data governance, and equitable access to AI technologies. Sustainable development strategies must include policies that ensure the ethical and inclusive use of AI, balancing technological advancement with social and environmental considerations. Also AI has the potential to accelerate progress toward Nigeria's sustainable development goals. However, addressing key challenges such as inequality, job displacement, and data privacy is crucial to ensuring that AI contributes positively to the country's long-term social, economic, and environmental sustainability.

Keywords: *Artificial Intelligence, technological advancement, sustainable development*

Introduction

Rapid advances in artificial intelligence (AI) are transforming how societies organize production, deliver public services, and solve complex social problems. AI broadly, systems that perceive data, learn from it, and make or support decisions offers tools that can accelerate progress toward many of the United Nations' Sustainable Development Goals (SDGs), including good health and well-being, quality education, clean energy, sustainable cities, decent work and economic growth, and reduced inequalities. For low and middle-income countries, AI promises efficiency gains, better targeting of scarce resources, and novel solutions to persistent development challenges.

Artificial intelligence (AI) has progressively transformed from a niche technological innovation to a powerful tool capable of solving complex and multidimensional problems across various sectors (Bibri et al., 2024, Mienye and Jere, 2024a, Neethirajan, 2024). Its applications in sustainable development are promising, offering state-of-the-art changes in areas crucial for economic growth, social equity, and environmental sustainability (Singh et al., 2024, Triguero et al., 2024). AI systems use algorithms and dynamic modeling to process data, make decisions, and learn from outcomes, often surpassing the speed and

accuracy of human capabilities in various tasks (Mienye & Jere, 2024c). AI holds immense potential to accelerate sustainable development in Africa, its application faces several challenges that are not adequately addressed in current research. In Nigeria as Africa, where the challenges are as diverse as they are significant, AI offers a promising tool to accelerate progress towards the sustainable development goals (SDGs) established by the United Nations in 2015 (Palomares et al., 2021). These goals aim to address global challenges such as poverty, inequality, climate change, environmental degradation, peace, and justice (Bickley, Macintyre, & Torgler, 2024). For example, AI-powered applications in agriculture can predict weather patterns and optimize planting cycles, thus boosting crop yields and resilience to climate variability (Javaid et al., 2023, Shaikh et al., 2022). In healthcare, AI models are being developed to diagnose diseases from medical images, significantly improving the reach and quality of medical services in underserved regions (Bohr and Memarzadeh, 2020, Schwalbe and Wahl, 2020).

Nigeria, as Africa's most populous country and largest economy by several measures, stands at a pivotal intersection of rapid digital adoption and pressing development needs. Persistent challenges such as health service access gaps, food security vulnerabilities, under-resourced education systems, urban infrastructure deficits, energy instability, and governance/administration capacity limits create an environment where high-impact, scalable technological interventions could produce significant benefits. At the same time, Nigeria faces structural constraints that shape how effectively AI can contribute to development outcomes: uneven digital infrastructure (broadband access and stable electricity), skills shortages in data science and AI, limited availability of high-quality, representative data, nascent regulatory frameworks and policy capacity, and concerns about equity, bias, privacy, and job displacement.

This study is motivated by the need to systematically understand how AI can be aligned with Nigeria's SDG priorities in ways that are both effective and equitable. There is a gap in empirical evidence about which AI interventions deliver measurable SDG outcomes at scale in the Nigerian context, what governance and institutional arrangements facilitate safe/ethical deployment, and how trade-offs (for example, efficiency vs. employment impacts, or innovation vs. privacy) should be managed. Filling this gap will help policymakers, development partners, private sector actors, and civil society make informed decisions on investments, regulations, and capacity building so that AI becomes a tool for sustainable development rather than an unregulated disruptor.

Conceptual Clarifications

Artificial Intelligence (AI)

Artificial intelligence (AI) has progressively transformed from a niche technological innovation to a powerful tool capable of solving complex and multidimensional problems across various sectors (Bibri, Krogstie, Kaboli, & Alahi, 2024; Mienye & Jere, 2024; Neethirajan, 2024). AI can be characterized as the branch of computer science that focuses on the creation of intelligent agents, which are systems that perceive their environment and take actions that maximize their chances of successfully achieving their goals (Tiwari, 2024). This involves the simulation of cognitive processes that are associated with human intelligence, such as learning, reasoning, problem-solving, perception, and language understanding (Harika, Baleeshwar, Navya, & Shanmugasundaram, 2022). Nils(2010) opines that Artificial intelligence is that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment. Rebeiro(2021) also defines AI as the field of computer science that enables machines to perform tasks requiring human-like intelligence.

Sustainable development:

Sustainable development, refers to the organizing principle for meeting human development goals while simultaneously sustaining the ability of natural systems to provide the natural resources and ecosystem services upon which the economy and society depend (Liu et al., 2018, Mensah, 2019). Many scholars and institutions are unanimous on the definition of sustainable development Acording to the Sustainable Development Commission of the United Kingdom (2011) and International Institute for sustainable development (2023) Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs. Sustainable development practices help countries grow in ways that adapt to the challenges posed by climate change, which will in turn help to protect important natural resources for ours and future generations (Steinbrink 2019). Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs (Nwoye, 2023).

Theoretical framework

Machine Learning (ML) theory were laid by Arthur Samuel (1959), who defined machine learning as *"the field of study that gives computers the ability to learn without being explicitly programmed."* Theory is a branch of Artificial Intelligence (AI) that focuses on developing algorithms and mathematical models that enable computers to learn patterns from data and make predictions or decisions without being explicitly programmed for every task. The central idea is that systems can improve their performance automatically through *experience* (data) rather than relying only on rigidly pre-defined instructions. The theory emerged from a combination of statistics, computer science, and cognitive science, and is rooted in the concept that learning can be understood as the ability to generalize from examples. A machine learning system is trained on datasets and then applies the learned model to new, unseen data.

Machine Learning Theory provides a foundation for understanding how Artificial Intelligence systems can contribute to achieving Sustainable Development Goals (SDGs). According to Arthur Samuel (1959), ML gives computers the ability to learn from data without explicit programming, while Mitchell (1997) emphasized that performance improves through experience. This principle is highly relevant to Nigeria, where development challenges are complex, data-driven, and context-specific. Machine Learning Theory underpins how AI can accelerate Nigeria's progress toward the SDGs. By enabling systems to learn from Nigeria's unique social, economic, and environmental data, ML transforms raw information into actionable insights that improve health, education, agriculture, governance, and energy efficiency. However, success depends on addressing Nigeria's challenges of data quality, digital infrastructure, ethical governance, and local capacity-building to ensure equitable benefits.

Contributions and the potential influence of AI to sustainable development goals in Nigeria

Artificial Intelligence (AI) has become an essential driver of innovation and transformation in contemporary societies. Its integration into diverse sectors such as health, agriculture, education, governance, and energy has demonstrated significant potential for accelerating progress toward the Sustainable Development Goals (SDGs). For a country like Nigeria, where developmental challenges are multi-dimensional and complex, AI presents an opportunity to bridge systemic gaps, optimize resource utilization, and generate sustainable solutions that align with the 2030 Agenda.

AI and SDG 3: Good Health and Well-Being: In the health sector, AI has already contributed through diagnostic tools, telemedicine platforms, and disease detection systems. For example, AI-based algorithms are increasingly used in Nigerian hospitals to analyze radiological images, detect malaria parasites, and monitor maternal health risks.

These applications improve the accuracy of diagnoses and extend healthcare access to underserved communities. Public and private healthcare centers can use AI robo-advisors and AI chat bots to offer good nutrition, balance diet and healthy lifestyle recommendations on their websites free-of-charge so that everybody, both rich and poor, women and girls, can have access to such information and use it to improve their health and wellbeing (Schwalbe and Wahl, 2020)**.** The potential influence of AI in this domain is substantial. AI-driven disease surveillance systems can predict and contain outbreaks of infectious diseases such as malaria, cholera, and Lassa fever. Furthermore, the development of personalized medicine, tailored to individual patient needs through machine learning models, could drastically improve treatment outcomes and reduce mortality rates. By addressing systemic weaknesses in Nigeria's healthcare infrastructure, AI has the capacity to accelerate progress toward achieving SDG 3.

AI and SDG 2: Zero Hunger: Agriculture remains a cornerstone of Nigeria's economy, and AI has been increasingly deployed to support farmers in improving productivity. Current contributions include the use of AI-powered mobile applications to provide farmers with real-time weather forecasts, pest control advice, and early warning systems for crop diseases. Predictive models also help optimize the use of fertilizers and irrigation, reducing waste and costs. The potential influence of AI is even more transformative. AI-enabled precision agriculture could significantly enhance crop yields and resilience to climate change. In addition, AI-driven supply chain optimization would improve storage, distribution, and market access, thereby reducing post-harvest losses and enhancing food security. Such interventions directly support Nigeria's attainment of SDG 2. Purchase of essential inputs such as seeds, fertilizer, farming technology, and water. AI tools can be used to detect early any shortage of funds that may prevent smallholder farmers from farming, achieving their potential harvests and limit their ability to feed their communities

and deliver agricultural produce to markets thereby increasing hunger (Shankar et al, 2020).

AI and SDG 4: Quality Education: In education, AI-enabled platforms are already being used to provide personalized learning experiences and automated assessment tools. These innovations reduce the burden on teachers and enhance the learning process by adapting content to individual student needs. Educators can use AI tools to support teaching to girls and boys effectively. AI can be used to simplify complex concepts to aid understanding in classrooms (Pedro et al, 2019). The potential influence of AI in this sector is considerable. AI can help address Nigeria's persistent teacher–student ratio imbalance by supplementing classroom instruction, particularly in rural areas where qualified teachers are scarce. Furthermore, adaptive learning technologies have the capacity to reduce dropout rates by keeping learners engaged and tailoring instruction to their learning pace. By expanding access to quality education, AI becomes a crucial driver for achieving SDG 4.

AI and SDG 7: Affordable and Clean Energy: AI is gradually being applied to energy systems in Nigeria. Current contributions include predictive analytics for solar energy management and pilot projects in smart grid optimization. These technologies improve energy distribution and efficiency in a country where electricity supply is notoriously unreliable. AI tools can also be used to predict future contamination of water using historical data on water pollution (Jogee et al, 2024). This will enable the authorities to know the parameters to monitor continuously and to build safeguards in water supply systems towards preventing the contamination of water in the future. The potential influence of AI in this domain is transformative. AI can forecast energy demand, detect grid failures in real time, and optimize the integration of renewable energy sources. By expanding access to clean and affordable energy, particularly in off-grid rural communities, AI could play a pivotal role in Nigeria's pursuit of SDG 7.

AI and SDG 11: Sustainable Cities and Communities: Rapid urbanization has posed significant challenges for Nigeria's cities, including traffic congestion, pollution, and inadequate waste management. AI has already been introduced in some cities for traffic monitoring and security surveillance. In the future, AI could be applied more broadly to urban planning, predictive flood management, and smart transportation systems. By providing city managers with real-time data for decision-making, AI can help create more sustainable, resilient, and inclusive urban environments, thereby advancing SDG 11.

AI and SDG 8 & 9: Decent Work, Economic Growth, and Innovation: Nigeria's fintech sector demonstrates AI's contribution to economic growth. AI is currently used in fraud detection, mobile banking, and credit risk assessment, enabling financial inclusion for previously underserved populations. AI-driven automation is also improving efficiency in logistics, manufacturing, and customer services. Potentially, AI could significantly boost Nigeria's industrial productivity and create new opportunities for entrepreneurship. However, this will require deliberate policies to balance automation with job creation and reskilling initiatives. Properly harnessed, AI can strengthen Nigeria's innovation ecosystem and contribute to both SDG 8 and SDG 9. The authorities can also encourage all firms to use AI human-resources tools to profile their employees correctly and ensure that workers' personally identifiable information is not used as a basis for workplace discrimination (Cachat-Rosset and Klarsfeld, 2023).

AI and SDG 16: Peace, Justice, and Strong Institutions: AI has already been deployed in Nigeria for election monitoring, corruption detection, and real-time data analysis in governance. Natural language processing applications are also used to translate government information into local languages, enhancing civic participation. Looking forward, AI could strengthen transparency and accountability through improved data analytics and fraud detection systems. Predictive analytics, if ethically managed, may also

enhance national security by identifying patterns of criminal or terrorist activity. By promoting good governance, AI directly contributes to SDG 16. AI systems can be used to promote peace, justice, and strong institutions in several ways (Dasandi and Mikhaylov, 2019). AI systems can be used to collect and analyse granular unstructured resource allocation data that can reveal areas where there are unfair distribution of public resources and deprivation of human rights, which can potentially lead to conflict, war, feeling of injustice and persecution.

2.5 Effects of AI on sustainable development in Nigeria,

AI's effects on sustainable development have been mixed (Lammers et al., 2022). However, no prior published study systematically predicts the extent to which AI may influence each facet of Sustainable Development Goals (SDGs) over time in different developed and developing countries.3 This indicates a crucial research gap, as anecdotal evidence indicates that AI might impact on the capacity to achieve each SDG (Leal Filho et al., 2022). In Nigeria, however, the dual nature of AI's influence is amplified by structural constraints such as limited infrastructure, skills shortages, and regulatory gaps. First, the analysis highlights that AI-driven interventions are already contributing positively to sectors directly tied to the Sustainable Development Goals (SDGs). For instance, in health, diagnostic AI tools and predictive analytics are helping to bridge gaps caused by shortages of medical specialists. Similarly, in agriculture, precision advisory systems powered by AI have demonstrated potential in increasing smallholder productivity and reducing input waste. These findings are consistent with emerging empirical evidence from other Sub-Saharan African contexts where AI-based agritech solutions have improved crop yields and reduced losses (World Bank, 2024). Nonetheless, the discussion also reveals significant challenges that threaten to undermine these benefits. The digital divide remains a critical barrier: rural farmers, low-income households, and under-resourced schools have limited access to electricity, internet connectivity, and digital

devices, which limits the uptake of AI solutions. Without deliberate inclusion strategies, AI could deepen existing inequalities rather than reduce them. This observation echoes earlier concerns raised by analysts that technology diffusion in Africa often reproduces socio-economic disparities unless embedded in inclusive policies (PwC Nigeria, 2023).

Another important dimension relates to governance and ethics. While AI holds promise for improving service delivery and enhancing public sector transparency, it also poses risks of surveillance, biased decision-making, and privacy violations if not properly regulated. Nigeria's emerging National AI Strategy is therefore timely, as it provides a policy foundation for guiding responsible AI use (NITDA, 2023). However, gaps in enforcement capacity and institutional readiness may limit the effectiveness of these frameworks. The risk here is that AI may be adopted faster than Nigeria's regulatory and ethical safeguards can adapt, leading to unintended social harms. From an economic perspective, AI presents both opportunities and risks for employment. On the one hand, AI adoption can stimulate new sectors such as fintech, data services, and e-commerce, creating high-value jobs and entrepreneurial opportunities (Adepoju, 2023; UNESCO, 2023). On the other hand, automation of routine tasks may displace low-skill workers, particularly in manufacturing and service sectors. Unless proactive reskilling and social protection measures are implemented, the net impact could exacerbate unemployment and inequality. This mirrors global debates on the "future of work," where AI's benefits are unevenly distributed between highly skilled digital workers and vulnerable low-wage earners (ILO, 2023).

Environmental impacts represent another complex trade-off. AI has been shown to aid in climate modelling, disaster prediction, and natural resource monitoring, all of which are highly relevant for Nigeria's climate resilience (UNDP, 2024). However, the energy demands of large-scale AI systems raise sustainability questions in a country already grappling with unreliable electricity and dependence on fossil fuels (UNESCO, 2023; PwC Nigeria, 2023). Integrating green AI practices and renewable energy sources into Nigeria's

digital infrastructure is thus crucial if AI is to contribute meaningfully to SDG 13 (climate action). The effects of AI on sustainable development in Nigeria cannot be considered in binary terms of "positive" or "negative." Rather, the outcomes depend on the interplay between technological capabilities, institutional readiness, socio-economic structures, and policy frameworks (CIPIT, 2025). AI is best understood as an enabler whose developmental impact will vary depending on how Nigeria invests in infrastructure, data ecosystems, regulatory systems, and human capital.

Review of related literature

The integration of AI in sustainable development has been the subject of extensive research globally, though the focus on Africa is comparatively recent. Several works have highlighted the potential of AI in promoting sustainable development goals worldwide. For instance, Vinuesa et al. (2020) provided a systematic review of how AI impacts all seventeen SDGs, noting that while AI has the potential to enable achievements across all goals, it also poses risks that could hinder progress if not managed carefully. Similarly, Rolnick et al. (2022) discussed how machine learning (ML) could address key challenges in climate prediction, agriculture, and energy consumption, which are essential for environmental sustainability.

Ayana et al. (2024) evaluated the effectiveness of current AI policies in several African countries, identifying gaps in data governance, which could hinder equitable access to AI technologies. They argue for more comprehensive regulations to safeguard against biases and ensure ethical AI usage across different sectors. Similarly, Mir, Kar, and Gupta (2022) highlighted the importance of AI literacy among policymakers and stakeholders to better understand the socio-economic impacts of AI, especially in areas with limited digital infrastructure. These insights underline the critical need for AI policy reform and capacity building to maximize AI's impact on sustainable development.

Okolo, Aruleba, and Obaido (2023), which analyzed the existing AI policies in Nigeria, South Africa, and Kenya. Their research suggests that while these countries are making strides in creating conducive environments for AI innovations, gaps in regulation and alignment with global standards remain a concern.

Olatunde, Adelani, and Sikhakhane (2024) investigated the application of AI in water resource management in Africa and the United States. Their findings illustrate how AI can optimize the distribution and usage of water resources, significantly impacting agriculture and sanitation sectors, which are critical for sustainable development. These studies emphasize the tangible benefits of AI in sector-specific challenges, highlighting its potential to transform essential services and infrastructure in Africa.

Ibomoiye, Yanxia, Ileberi (2024) Examined the Artificial Intelligence (AI) techniques are transforming various sectors and hold significant potential to advance sustainable development in Africa. This study reviews the current state of sustainable development in Africa, highlighting the role AI can play in driving progress across key sectors, including healthcare, agriculture, education, environmental protection, and infrastructure. The study proposes a comprehensive framework for integrating AI into Africa's sustainable development efforts, offering tailored AI-driven strategies that align with the continent's unique context.

Conclusion

Artificial Intelligence has emerged as a transformative technology with the potential to accelerate the achievement of the Sustainable Development Goals (SDGs) in Nigeria. The review of literature shows that AI applications in healthcare, agriculture, education, governance, and financial inclusion can improve efficiency, decision-making, and service delivery. For instance, AI-driven agricultural technologies can enhance food security, while AI-enabled health systems can expand access to quality medical services.

Furthermore, AI supports climate action, smart infrastructure, and economic growth through innovative business models and digital entrepreneurship. Government alone cannot drive AI adoption. Strong partnerships with private technology firms, academic institutions, civil society organizations, and international development agencies are essential. PPPs can foster innovation hubs, technology incubators, and collaborative research that focus on local solutions for agriculture, healthcare, education, and environmental sustainability. Collaborative efforts will also ensure that AI innovations are tailored to Nigeria's socio-economic realities rather than imported wholesale.

However, challenges such as inadequate digital infrastructure, low AI literacy, high implementation costs, weak data governance frameworks, and ethical concerns about bias and job displacement remain major barriers. Nigeria's progress toward SDGs will depend on how effectively it leverages AI while addressing these structural and policy gaps. If strategically integrated into development plans, AI can serve as a catalyst for inclusive and sustainable growth, reducing inequalities and fostering innovation.

Recommendations

1. AI has the potential to accelerate progress toward Nigeria's sustainable development goals. However, addressing key challenges such as inequality, job displacement, and data privacy is crucial to ensuring that AI contributes positively to the country's long-term social, economic, and environmental sustainability
2. Nigeria must prioritize the development of robust digital infrastructure as a foundation for AI adoption. This includes expanding access to high-speed internet across urban and rural areas, investing in reliable electricity supply, and establishing national data centers to support big data analytics.

3. A clearly defined national AI strategy should be established to guide AI adoption in line with the SDGs. This framework should emphasize ethical AI use, privacy protection, intellectual property rights, and cybersecurity.

4. There is an urgent need to embed AI literacy in Nigeria's education system. At the primary and secondary levels, digital literacy should be prioritized to prepare learners for a knowledge-driven economy.

5. Nigeria should collaborate with global AI leaders, regional organizations, and international development partners to share knowledge, best practices, and technological expertise. By participating in global AI alliances and research networks, Nigeria can learn from successful AI deployments in other countries and adapt them to its local context.

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