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Cost-Benefit Analysis of Artificial Intelligence for Environmental Sustainability in Nigeria

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ABSTRACT

This study evaluates the cost–benefit dynamics of artificial intelligence (AI) in advancing environmental sustainability in Nigeria. Using a survey design, data were collected from 1,200 respondents across six geopolitical zones and analysed using descriptive statistics and multiple regression techniques. The findings reveal that although AI implementation entails relatively high costs (mean = 3.8), its environmental (mean = 4.2) and economic benefits (mean = 4.0) are substantial. Regression results indicate a strong positive effect of AI benefits on sustainability outcomes ($\beta = 0.68$, $p < 0.05$), while costs exert a negative but significant influence ($\beta = -0.35$). Overall, the results confirm that the benefits of AI outweigh its costs, supporting its economic and environmental viability. The study concludes that AI is a critical enabler of sustainable environmental management in Nigeria, particularly in enhancing monitoring, efficiency, and decision-making. It recommends increased government investment in AI infrastructure, development of supportive regulatory frameworks, promotion of public–private partnerships, and capacity building through education and training. These measures are essential for overcoming cost barriers and maximising the sustainability potential of AI technologies in Nigeria.

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INTRODUCTION

The growing urgency of environmental degradation, climate change, and resource depletion has intensified the search for innovative and scalable solutions globally. In Nigeria, environmental challenges such as oil spills, deforestation, urban pollution, and waste mismanagement continue to undermine sustainable development goals. Against this backdrop, artificial intelligence (AI) has emerged as a transformative tool capable of enhancing environmental monitoring, prediction, and management (Bianchi & Putro, 2024). AI-driven systems offer advanced data analytics, automation, and real-time decision-making capabilities that can significantly improve environmental sustainability outcomes. Recent global discourse has emphasised the dual nature of AI: it facilitates efficient environmental solutions, but it also incurs economic, ethical, and infrastructural costs (Kumar, 2025). In developing economies like Nigeria, where digital infrastructure and governance systems are still

evolving, the cost-benefit dynamics of AI adoption for environmental sustainability remain underexplored.

The deployment of AI technologies such as remote sensing, machine learning models for climate prediction, and smart waste management systems requires substantial investments in infrastructure, technical expertise, and regulatory frameworks (Olawade et al., 2024). Nigeria's environmental sustainability challenges are particularly complex due to socio-economic inequalities, governance gaps, and limited technological adoption. AI applications for environmental sustainability can potentially address issues such as illegal deforestation monitoring, flood prediction, air quality assessment, and energy efficiency optimisation. However, the economic viability of such technologies depends on a careful evaluation of both direct and indirect costs and benefits, including environmental impact reduction, economic returns, and social implications (Belyamani, 2025). The concept of cost–benefit analysis (CBA) provides a systematic framework for evaluating the economic feasibility of AI technologies in environmental sustainability. CBA enables policymakers and stakeholders to assess whether the benefits derived from AI implementation outweigh the associated costs. While developed countries have increasingly integrated AI into environmental governance, empirical evidence from Nigeria remains limited, creating a significant research gap (Abuja, Nigeria & Chuntar, 2025).

Furthermore, the integration of AI in environmental sustainability aligns with global frameworks such as the United Nations Sustainable Development Goals (SDGs), particularly Goals 7 (Affordable and Clean Energy), 11 (Sustainable Cities), and 13 (Climate Action). However, achieving these goals in Nigeria requires context-specific strategies that consider local environmental, economic, and institutional factors(Mhlanga & Shao, 2024), such as the unique challenges posed by Nigeria's diverse ecosystems, economic conditions, and governance structures. This study contributes to the literature by providing a comprehensive cost–benefit analysis of AI applications for environmental sustainability in Nigeria. It integrates theoretical perspectives with empirical data to evaluate the economic, environmental, and social implications of AI adoption. The findings are expected to inform policymakers, researchers, and practitioners about optimising AI investments for sustainable development.

The aim of this study is to evaluate the cost–benefit dynamics of artificial intelligence in promoting environmental sustainability in Nigeria.

Specific objectives are to:

1. Examine the costs associated with AI adoption for environmental sustainability.
2. Assess the environmental and economic benefits of AI implementation.
3. Determine the relationship between AI investment and sustainability outcomes.
4. Provide policy recommendations for optimising AI deployment.

Research Questions

1. What are the major costs associated with AI adoption for environmental sustainability in Nigeria?
2. What benefits does AI provide in enhancing environmental sustainability?
3. What is the relationship between AI investment and sustainability outcomes?

Research Hypotheses

H_{01}: AI adoption has no significant effect on environmental sustainability in Nigeria.

H_{02}: The benefits of AI do not significantly outweigh the costs in environmental applications, particularly in terms of resource allocation, implementation challenges, and potential negative impacts on local ecosystems.

THEORETICAL LITERATURE

Cost–Benefit Analysis Theory

Cost–Benefit Analysis (CBA) theory provides a systematic framework for evaluating economic decisions by comparing total expected costs against anticipated benefits(Cao Thi, 2025). It incorporates both tangible and intangible outcomes, enabling policymakers to determine the economic feasibility and efficiency of investments such as AI-driven environmental sustainability initiatives.

Technology Acceptance Model (TAM)

The Technology Acceptance Model explains how users come to accept and use new technologies based on their perceived usefulness and ease of use (Venkatesh et al., 2021). In environmental contexts, TAM highlights how stakeholders' attitudes, technological literacy, and institutional readiness influence AI adoption and its effectiveness in sustainability initiatives, ultimately impacting the success of projects aimed at achieving sustainable development goals.

Sustainable Development Theory

Sustainable Development Theory emphasises the need to balance economic growth, environmental protection, and social equity to meet present needs without compromising future generations(Sharma, 2024). It underscores the role of innovative technologies, like AI, in optimising resource use, reducing environmental degradation, and supporting long-term ecological sustainability. The integration of these three theories provides a comprehensive framework for analysing AI adoption's environmental sustainability. Cost–benefit analysis theory evaluates the economic viability of AI investments by assessing whether environmental and economic gains outweigh implementation costs. The Technology Acceptance Model complements this framework by explaining how stakeholders' perceptions, institutional capacity, and technical readiness influence the adoption and utilisation of AI technologies in Nigeria. Meanwhile, sustainable development theory situates the study in a broader global context, emphasising that AI-driven environmental solutions must achieve a balance between ecological preservation, economic efficiency, and social inclusiveness. Collectively, these theories highlight that the success of AI in environmental sustainability depends not only on financial justification but also on user acceptance and alignment with long-term sustainability goals. Their integration is critical because it bridges economic evaluation, behavioural adoption, and environmental impacts, thereby providing a multidimensional understanding of AI deployment in Nigeria.

Empirical Literature Review

Recent studies indicate that AI significantly enhances environmental sustainability through predictive analytics, automation, and data optimisation(Jain & Mitra, 2024) . For instance, AI-driven climate models improve disaster prediction accuracy, reducing economic losses (Kim & Kim, 2025). In Africa, AI applications in agriculture and environmental monitoring have shown promising results. Studies reveal that AI-based systems improve crop yields and reduce environmental degradation (Huh, 2025). However, high implementation costs and limited technical expertise remain major barriers, particularly in rural areas where access to technology and training is often insufficient.

In Nigeria, emerging research suggests that AI can improve waste management efficiency and pollution monitoring. For instance, AI-powered smart waste systems have demonstrated a reduction in urban waste accumulation (Kelechi et al., 2025). Similarly, AI-driven systems for detecting oil spills enhance environmental response in the Niger Delta. Despite these benefits, the costs associated with AI adoption are substantial. Infrastructure development, data acquisition, and skilled personnel training require significant investment (Mam et al., 2025). Additionally, energy consumption by AI systems raises environmental concerns, potentially offsetting sustainability gains, especially in regions where energy sources are not renewable and contribute to carbon emissions. Studies also highlight socio-economic challenges, including digital inequality and governance limitations, which affect AI implementation in developing countries (Narayan Nath, 2025). These challenges are particularly relevant in Nigeria, where infrastructural deficits and policy gaps hinder technological adoption, leading to increased difficulties in leveraging AI for economic growth and sustainability. Existing studies largely focus on the benefits of AI without providing a comprehensive cost–benefit analysis in the Nigerian context. This study fills this gap by integrating economic evaluation with environmental sustainability outcomes.

METHODOLOGY

This study adopts a quantitative survey research design to examine the cost–benefit dynamics of artificial intelligence in environmental sustainability across Nigeria. The study covers all six geopolitical zones: North Central, North East, North West, South East, South, and South West to ensure national representativeness. A stratified random sampling technique was employed to select

six states: Lagos, Rivers, Abuja (FCT), Kano, Enugu, and Borno. These states were purposively selected based on their strategic economic, technological, and environmental relevance. The study population comprises environmental experts, policymakers, AI professionals, academics, and non-governmental organisation (NGO) workers. A total sample size of 1,200 respondents was determined using a proportional allocation method. Data were collected through structured questionnaires designed on a five-point Likert scale, complemented by secondary data from policy reports and environmental databases. To ensure reliability and validity, the instrument was subjected to pilot testing, yielding a Cronbach's alpha coefficient of 0.87, indicating high internal consistency. Ethical considerations were strictly adhered to, including informed consent, voluntary participation, confidentiality, and anonymity of respondents. Data collection was conducted both physically and digitally to enhance coverage and response rate. The collected data were analysed using descriptive statistics (mean and standard deviation) and inferential statistics (multiple regression analysis) to test the study hypotheses. These analytical techniques were chosen due to their robustness in examining relationships between AI costs, benefits, and environmental sustainability outcomes.

Table 1: Demographic Distribution

Zone	State	Respondents	Occupation	Age	Sex	Education	Questionnaire Distributed	Questionnaire Returned
South-South	Rivers	200	Engineers/Researchers	25-55	M/F	B.Sc-PhD	220	200
South-West	Lagos	250	Tech Professionals	24-50	M/F	BSc-PhD	270	250
South-East	Enugu	190	Environmentalists	25-50	M/F	BSc-PhD	210	190
North-Central	Abuja	200	Policymakers	30-60	M/F	MSc-PhD	220	200
North-West	Kano	180	Academics	28-55	M/F	BSc-PhD	200	180
North-East	Borno	180	NGOs	30-60	M/F	Diploma-MSc	200	180

Source: Authors Fieldwork, 2026

Table 1 presents the demographic characteristics of respondents across Nigeria's geopolitical zones. The distribution ensures national representation, with Lagos and Rivers having higher participation due to technological advancement. Occupations include professionals relevant to AI and environmental sustainability, ensuring informed responses, such as data scientists, environmental consultants, and policy analysts who contribute valuable insights to the study. Age distribution reflects a working population actively engaged in decision-making processes. Educational qualifications range from diploma to PhD, indicating a high level of expertise among respondents. The high questionnaire return rate demonstrates strong engagement and reliability of the data collected, supporting the validity of subsequent statistical analyses. The selected states represent diverse socio-economic, environmental, and technological contexts in Nigeria. Lagos State was chosen due to its status as Nigeria's technological and economic hub, with significant AI adoption and smart city initiatives. Rivers State represents the Niger Delta region, where environmental degradation from oil exploration necessitates advanced monitoring technologies. Abuja (FCT) was selected for its role as an administrative centre, housing policymakers, and regulatory institutions critical to AI governance. Kano State represents the North-West region with growing industrial and agricultural activities, making it relevant for AI-driven environmental applications. Enugu State reflects the South-East's emerging technological and academic landscape, while Borno State represents the North-East, where environmental challenges such as desertification

and climate-induced displacement require innovative solutions. This selection ensures a balanced representation of Nigeria's environmental challenges and technological readiness across regions.

Data Analysis

Table 2: Descriptive Statistics

Variable	Mean	Statistics
AI Cost	3.8	0.65
Environmental Benefit	4.2	0.58
Economic Benefit	4.0	0.60

Source: Authors Fieldwork, 2026

The descriptive statistics reveal that respondents perceive AI-related costs as relatively high (mean = 3.8), reflecting infrastructural and operational expenses. However, environmental benefits (mean = 4.2) are rated highest, indicating strong agreement about AI's effectiveness in sustainability. Economic benefits (mean = 4.0) also show positive perception, suggesting that AI contributes to efficiency and long-term savings. The low standard deviations indicate consistency in responses across the sample. Overall, the results suggest that, despite the high costs, the perceived benefits of AI in environmental sustainability are substantial.

Table 3: Regression Analysis

Variable	β	t-value	p-value
AI Cost	-0.35	-4.12	0.000
AI Benefit	0.68	7.45	0.000

$R^2 = 0.62$

Source: Authors Fieldwork, 2026

The regression results indicate that AI benefits significantly influence environmental sustainability ($\beta = 0.68$, $p < 0.05$), confirming a strong positive relationship. Conversely, AI costs have a negative effect ($\beta = -0.35$), suggesting that high costs may hinder adoption. AI-related variables explain 62% of sustainability outcomes, as indicated by the R^2 value of 0.62. These findings highlight that while costs are a barrier, the benefits substantially outweigh them, supporting the economic viability of AI investments in Nigeria's environmental sector.

DISCUSSION OF FINDINGS

The findings of this study reveal that while the cost of AI implementation in environmental sustainability is relatively high (mean = 3.8), the perceived environmental (mean = 4.2) and economic benefits (mean = 4.0) are significantly greater. This indicates that stakeholders recognize the transformative potential of AI despite financial constraints. The regression analysis further strengthens this observation, showing a strong positive relationship between AI benefits and environmental sustainability outcomes ($\beta = 0.68$, $p < 0.05$), while AI costs exhibit a negative but significant relationship ($\beta = -0.35$). These results align with the cost–benefit analysis theory, which posits that investments are justified when the benefits outweigh the costs. In this study, the high environmental and economic benefits relative to costs suggest that AI adoption is economically viable in Nigeria. The findings also support sustainable development theory, as AI contributes to improved resource efficiency, pollution monitoring, and environmental conservation, thereby promoting long-term sustainability. Furthermore the Technology Acceptance Model gives insight into the observed dynamics, as stakeholders' positive perception of AI benefits likely drives its adoption despite cost barriers. This is consistent with empirical studies such as (Achebo, 2025), which emphasise AI's role in enhancing climate mitigation, and (Umar et al., 2025), which highlight adoption challenges in developing economies.Overall, the integration of descriptive and regression results indicates that, although cost remains a constraint, the significant benefits of AI for environmental sustainability justify increased investment and policy support in Nigeria.

CONCLUSION

This study concludes that artificial intelligence presents a viable and transformative solution for addressing environmental sustainability challenges in Nigeria. Although the cost of implementation remains relatively high, the environmental and economic benefits significantly

outweigh these costs, making AI a worthwhile investment. The findings demonstrate that AI enhances environmental monitoring, resource efficiency, and decision-making processes, thereby contributing to sustainable development goals. However, the study acknowledges certain limitations, including reliance on perceptual data and the cross-sectional nature of the research.

Future studies should adopt longitudinal designs to assess the long-term impact of AI on environmental sustainability. Additionally, further research could explore sector-specific applications of AI, such as agriculture, energy, and waste management, as well as the role of policy frameworks in facilitating adoption. Comparative studies across African countries would also offer a broader perspective on regional AI implementation.

RECOMMENDATIONS

1. The government should increase investment in AI infrastructure and provide policy frameworks that support AI adoption in environmental management, given the strong positive impact of AI benefits on sustainability outcomes.
2. Industry stakeholders should engage in public-private partnerships to reduce the financial burden of AI implementation and promote innovation in environmental technologies.
3. Universities and training centres should develop AI-focused curricula to address the skills gap identified as a barrier to adoption.4. Citizens should embrace AI-driven environmental solutions such as smart waste management systems and participate actively in sustainability initiatives.

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