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CONTRIBUTIONS OF ARTIFICIAL INTELLIGENCE (AI) ON ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE DEVELOPMENT IN TARABA STATE, NIGERIA

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Abstract

The paper determined the Contributions of Artificial Intelligence (AI) on Environmental Management for Sustainable Development in Taraba State, Nigeria. The field of AI is developing rapidly, revealing the potential for AI to advance human rights, improve labour conditions, protect the environment and prevent corruption. AI's ability to identify patterns and automate decision-making can dramatically increase efficiency, reduce waste and enhance monitoring and reporting across environmental, social and governance (ESG) efforts. AI is already delivering measurable environmental benefits across energy, conservation, pollution control, and waste management. One research question and one hypothesis guided the study. Survey research design was adopted for the study since it sought human opinions on the study. The population of the study was 746 lecturers in [redacted] Federal Tertiary institutions in Taraba State, Nigeria. The sample of the study was 224 selected through the simple random sampling technique. Questionnaire was the instrument used for the collection of data and it was validated by three experts. The reliability index for the study was 0.82 tested through the Cronbach Alpha procedure. The data was collected by the researchers and two research assistants. Mean and Standard deviation were used to

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analyse data collected on the research questions while t-test was used to test the hypothesis. The study found that AI aids in optimizing the use of renewable energy sources, AI aids in developing more effective strategies for disaster risk reduction, tracking deforestation in real time, cutting energy waste in buildings and data centers, protecting wildlife from poaching, sorting waste faster than humans can and reducing water loss in cities the carbon cost of itself. The findings also revealed that by leveraging AI, farmers can optimize irrigation, by leveraging AI, farmers can reduce fertilizer use and minimize waste, leading to more sustainable agricultural practices. The hypothesis tested was accepted. The study recommended among other that AI-powered precision farming techniques should be used to enable farmers to monitor soil conditions, weather patterns, and crop health with unprecedented accuracy.

Introduction

Artificial Intelligence (AI) plays a crucial role in promoting sustainable development by improving environmental management through the use of efficient energy systems and the incorporation of renewable energy sources. It aids in climate adaptation by utilizing advanced modeling techniques and early warning systems for natural disasters. The technology enhances environmental management through real-time pollution monitoring, optimized farming methods, and more efficient waste handling (Swanson, 2016). Nevertheless, its implementation presents challenges, such as substantial energy and water usage, concerns regarding data security, and the potential to exacerbate the digital divide. As we leverage AI's capabilities, it is essential to adopt a collaborative approach involving governments, businesses, academic institutions, and civil society. This joint effort is vital for establishing policies, standards, and practices that ensure the equitable distribution of AI's advantages while effectively addressing its challenges. By pursuing this path, it becomes feasible AI's role in sustainable development, making the planet more resilient, equitable, and prosperous for everybody. AI can find options for material reuse and recycling, durable and recyclable product design, and supply chain optimisation to lessen environmental impact by analysing data on material flows and product lifecycles. By forecasting energy demand and supply based on weather patterns, gird data, and consumption habits. AI is increasingly being used to optimise the development and operation of renewable energy systems, such as batteries, solar, and wind adjusting supply to ensure reliable energy access despite fluctuations in AI's benefits for environmental management adaptation and mitigation, according to Bessen (2019) are:

Energy Efficiency

AI optimises energy use and integrates renewable energy sources more effectively, reducing the carbon footprint of energy systems.

Handling Emergencies

Real-time air quality monitoring and forecasting are made possible by AI-driven systems, which support efforts to avoid and regulate pollution. AI improves urban trash and energy management, helping to create healthier, greener cities.

Pollution Monitoring and Control

AI-driven systems facilitate real-time monitoring and forecasting of air quality, aiding in pollution prevention and control efforts.

Smart Cities and Urban Planning

AI optimizes energy and waste management within urban areas, contributing to the design of greener, healthier cities.

Sustainable Agriculture

AI helps optimize agro-food production by improving resource efficiency and reducing the need for pesticides, fertilizers, and water.

Conservation

AI supports the monitoring and protection of endangered species and ecosystems, aiding in efforts to combat habitat loss and illegal activities.

Statement of the Problem

Artificial Intelligence has significant contribution to environment management. Artificial intelligence is a technology tool that can be used to track every sphere of life. AI can identify opportunities for repurposing and recycling materials, designing products for durability and recyclability, and optimising supply chains to reduce environmental impact. AI has emerged as a powerful tool in advancing the Sustainable Development Goals (SDGs). As societies around the world struggle with the difficult task of balancing economic development and environmental preservation, the incorporation of Artificial Intelligence (AI) technologies emerges as a promising avenue for driving sustainable practices and fostering resilience to environmental threats. Artificial Intelligence (AI) plays a crucial role in advancing environmental sustainability by offering innovative solutions to address complex challenges. AI is significant in earth system monitoring, highlighting its ability to revolutionise environmental data analysis and interpretation.

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Through AI-driven approaches, researchers can analyse large datasets more efficiently, leading to improved understanding of environmental processes and better-informed decision-making. However, its deployment poses challenges, including its own significant energy and water consumption, data security concerns, and the risk of widening the digital divide. It is against this backdrop that the researchers aimed at determining the Contributions of Artificial Intelligence on Environmental Management for Sustainable Development in Taraba State, Nigeria.

Purpose of the Study

The general purpose of the study is to examine the Contributions of Artificial Intelligence on Environmental Management for Sustainable Development in Taraba State. Specifically the study is posed to:

1. Investigate the contributions of AI on Environmental Management for sustainable development in Taraba State, Nigeria.

Research Questions

1. What are the contributions of AI on Environmental Management for sustainable development in Taraba State, Nigeria?

Research Hypotheses

1. There is no significant difference in the mean opinions of Federal Polytechnic Bali and Federal University Wukari lecturers on the contributions of AI on Environmental Management for sustainable development in Taraba State, Nigeria.

Significance of the Study

At the conclusion and publication of this research study different people will benefit from the research work such as the farmers, the lecturers, future researchers and the general public.

The farmers will benefit from this study because it will assist them to understand and use AI in earth system monitoring, highlighting its ability to revolutionize environmental data analysis and interpretation so as to know the crop health for better plant and harvest.

The study will be of a very big significance to lecturers because it will enable them carry out more research on this topic and to design curriculums that will suit AI on environmental sustainability.

Future researchers will benefit from this study as the copies of this publication will be placed in the libraries for reference purposes.

The general public will benefit from the study because the issue of environmental management and sustainability is becoming a problem to our environments therefore,

the study will enable the general public to understand the contribution of AI on environmental management so that they can make use of it.

Scope of the Study

The study is delimited to Federal institutions in Taraba State. It is also delimited to the lecturers in these institutions because these lecturers are in the position to offer factual information on contributions of artificial intelligence on climate change for sustainable development in Taraba State, Nigeria,

Sustainable Development Theory by Brundtland Commission (1987)

Sustainable development theory is a framework for balancing present needs with future needs by integrating economic prosperity, social equity, and environmental protection. Popularized by the Brundtland Commission in 1987, the theory defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Key pillars of sustainable development include ensuring responsible resource use, fair resource distribution, and the long-term health of natural systems to support human society. Environmental Protection: Conserving natural resources and ecosystems.

Sustainable Development Goals (SDGs):

The United Nations' 17 Sustainable Development Goals are a universal call to action to end poverty, protect the planet, and ensure peace and prosperity for all by 2030.

The Five Ps are:

The SDGs are organised around five overarching themes: people, planet, prosperity, peace, and partnerships. The implications and challenges of this are resource management which emphasises responsible and fair use of finite resources, recognising their limited supply; Interdependence whose theory highlights that economic progress, social inclusion, and environmental health are interconnected and must be managed simultaneously; criticism which states that some critics view the concept as an oxymoron, arguing that development is inherently unsustainable, or they are disappointed by the lack of progress in achieving sustainable development (Sadghi, 2019).

Environmental Management

The environment takes everything, or almost everything, according to the definition of the UNESCO organization; both human beings, both nature and the relationship between the two. It affects all human activities and is also affected by them (Sadghi, 2019). The author upheld that in terms of its functional characteristics, the environment is divided

into three categories: natural environment, socio-economic environment, and human-made environment. The management environment in the environmental field is better understood by management theories. In the views of Layzer (2002) four main theories of systems, cybernetics, disorder theory and contingency theory can be mentioned from the main and effective management theories in guiding environmental management. Environmental management is the decision-making process for regulating those human activities that have an impact on the environment, in such a way that the enduring capacity of the environment is not impaired for the development of human life (Lohani, 2024). The objective of environmental management is to promote the concept of sustainable development. But achieving sustainable development requires appropriate management tools. The environmental management system is one of these tools.

An environmental management system is a way to legitimize measures to protect the environment through corporate or institutional structures. An environmental management system is a set of management processes and procedures that allow an organization to analyse, control and reduce the environmental impact of its activities, products, and services, and operate more efficiently and effectively EMS is theoretically a tool for problem identification and problem solving, which is based on the concept of continuous improvement. This tool can be implemented in different ways depending on the type of activity and its needs for environmental management in each organization. An environmental management system consists of four main stages of the program, implementation, control, operation, or action that their relationship with each environmental management project takes place through a complete implementation cycle (Lohani, 2024; Sadghi, 2019; Layzer, 2002). .

Environmental Management and Sustainable Development

A fundamental and the key to this standard is to set up and maintain an environmental management system for standard requirements. According to Kusiak (2019) this element involves measuring and monitoring the impact of the organization's actions on the environment, taking action to prevent the continuation of the work and fixing it, registering test cases, and the results of inspections and reviews and audits of the environmental management system. That is, whether the environmental management activities are compatible with the environmental program and have the performances performed to control the effects? Given the global and sustainable goal of sustainable environmental management, local governments are called upon to develop sustainable sustainability plans to pursue global goals through local planning in cities. This requires the development of implementation tools and feasibility programs, one of these tools is the development of environmental management systems for cities, regions and urban neighbourhoods (LeCun, Bengio, & Hinton, 2015; Li et al, 2021).

Artificial Intelligence and Sustainable Development

As societies around the world struggle with the difficult task of balancing economic development and environmental preservation, the incorporation of Artificial Intelligence (AI) technologies emerges as a promising avenue for driving sustainable practices and fostering resilience to environmental threats. Furthermore, the key work of Hameed and Hussaini (2018) emphasized the critical role of AI in revolutionizing renewable energy optimization and management. Renewable energy systems may be fine-tuned for optimal efficiency using AI-powered predictive analytics and optimization methodologies, hastening the transition to a low-carbon energy future. According to Schiff et al., (2020), these developments not only enhance the resilience of energy infrastructure, but also help minimize greenhouse gas emissions and combat climate change on a global level. Artificial Intelligence (AI) plays a crucial role in advancing environmental sustainability by offering innovative solutions to address complex challenges. Schmitt et al. (2020) emphasize the significance of AI in earth system monitoring, highlighting its ability to revolutionize environmental data analysis and interpretation. Through AI-driven approaches, researchers can analyse large datasets more efficiently, leading to improved understanding of environmental processes and better-informed decision-making. Moreover, Zhang et al. (2018) underscore the importance of AI in optimizing renewable energy systems. AI algorithms enable the optimization of energy production and distribution, thereby maximizing energy efficiency and accelerating the transition to renewable energy sources. Additionally, Ahmed et al. (2021) discuss the potential of AI in water resource management, particularly in addressing water scarcity and pollution challenges. By leveraging AI technologies such as predictive modelling and real-time monitoring, stakeholders can optimize water distribution, enhance water quality, and improve overall water resource management practices. Wang et al. (2019) provided compelling case studies demonstrating AI's effectiveness in biodiversity conservation. AI-powered tools facilitate the monitoring and protection of biodiversity hotspots, contributing to global conservation efforts. These authors collectively highlight the transformative impact of AI in promoting environmental sustainability across various domains, from energy optimization to biodiversity preservation.

Santos and Carvalho (2025) deduced that applications of AI in environmental management are diverse, spanning areas such as climate change mitigation, agriculture optimization, ocean health monitoring, water resource management, weather forecasting, and disaster resilience (Ogundiran et al., 2024; Rautela et al., 2020). These technological advancements extend to energy efficiency in building environments sustainable asset management in construction to reduce waste (Rampini and Cecconi, 2022), and blockchain solutions that support low-carbon economies (Rani et al., 2024). Despite its potential, AI's environmental footprint, particularly regarding energy

consumption and carbon emissions, raises concerns about sustainability, calling for the development of eco-friendly AI solutions (Konya and Nematzadeh, 2024). Furthermore, ethical and governance issues must be addressed to ensure AI applications in environmental health align with public welfare goals (Adedayo Adefemi et al., 2023). While AI offers promising avenues for enhancing environmental health, its implementation requires clear governance frameworks to maintain transparency, safety, and ethical standards in technology use (Ansari et al., 2022).

Ongoing advancements in AI necessitate robust regulatory oversight to ensure transparency, safety, and ethical practices in environmental applications (Ansari et al., 2022). This highlights a critical need for further research on policy formation and practical implementation to fully harness AI's capabilities in environmental settings. Addressing these gaps will bridge the divide between AI's potential and its sustainable, practical, and ethical applications in environmental governance (Schiff et al., 2020).

Methods

The study's design is the survey research design. The research design is suitable for the study, since it seeks to document and describe what exists or the present status of existence or absence of what is investigated through collection of data on the opinions of lecturers in Federal Tertiary institutions in Taraba State. The population of the study is 425 lecturers in Federal Polytechnic Bali and 321 lecturers in Federal University Wukari all together is a population of 746 lecturers. The sample size of the study was two hundred and twenty four (224) federal tertiary institution lecturers in Taraba State, Nigeria. 128 lecturers were drawn from Federal Polytechnic Bali and 96 lecturers were selected from Federal University Wukari. Random same sampling technique was employed to select 30% from the respective population of each institution's lecturers. The research instruments was structured questionnaire of close ended questions developed by the researchers after proper review of literature. The 18-item questionnaire was titled '' Questionnaire on the Contribution of AI on Environmental Management for Sustainable Development (CAIEMSDQ).'' The Questionnaire was structured on a modified 4-point Likert scale of Strongly Agreed, Agreed, Disagreed and Strongly Disagreed with corresponding values of 4, 3, 2, and 1 respectively.

The instrument was face and content validated by three experts. Two from the Department of Agricultural and Bio- Environmental Engineering Technology Federal Polytechnic, Bali, one from Department of Measurement and Evaluation Federal University Wukari. Draft copies of the instrument alongside the title, purpose, research questions and research hypotheses of the study, were given to the experts. The experts were kindly requested to examine, scrutinize and make corrections and suggestions in terms of content, relevance, suitability, clarity and coverage of the dimensions of the

study. The corrections, suggestions, modifications and restructuring made by the experts were incorporated to produce the final copy of the instrument. The data generated from the pilot study was analysed using Cronbach Alpha reliability method to determine the internal consistency of the instrument and a coefficient index of 0.82 was obtained. The quantitative data was collected by the researchers with the help of one research assistant from each of the institutions under study. The researchers briefly explained to the research assistants how to administer and retrieve the questionnaires. Mean and Standard Deviation were employed to analyse the data collected to answer the research question. Null hypothesis was tested using the independent t-test at 0.05 level of significance and at the relevant degree of freedom. The decision rule for the research question was based on the upper and lower limits of the means scores thus:

SECTIONS B1-B2:

Strongly Agree	4	3.50 – 4.00
Agree	3	2.50 – 3.49
Disagree	2	1.50 – 2.49
Strongly Disagree	1	1.00 – 1.49

The mean and standard deviation were used to determine the degree of responses; the standard deviation was used to determine the extent to which respondents responses cluster or deviate around the mean. If the p-value of the null hypothesis is equal or greater than the Alpha value (0.05≥) and at the derived degree of freedom the hypothesis was retained and concluded that there is no significant difference between the respondents otherwise it was rejected.

Analyses of Data to Answer the Research Question

Data to answer the research question are analysed and presented in Table 4 to 5 as follows:

Research Question 1: What are the contribution of AI on environmental management for sustainable development in Taraba State, Nigeria?

Table 1: Computed Mean and standard deviation of responses on the contribution of AI on environmental management for sustainable development.

S/N	Item Statements	$\bar{X}$	SD	Remarks
1.	AI is used in tracking deforestation in real time	3.44	.60	Agreed
2.	AI is used in detecting methane leaks from space	3.50	.70	Strongly Agreed
3.	AI-powered precision farming techniques enable farmers to monitor soil conditions	3.24	.64	Agreed

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S/N	Item Statements	$\overline{X}$	SD	Remarks
4.	AI is used in sorting waste faster than humans can	3.58	.73	Strongly Agreed
5.	By leveraging AI, farmers can optimize irrigation	3.21	.62	Agreed
6.	By leveraging AI, farmers can reduce fertilizer use	3.48	.67	Agreed
7.	And minimize waste, leading to more sustainable agricultural practices	3.10	.89	Agreed
8.	Smart technology is being deployed in ecological monitoring	2.85	.84	Agreed
9.	AI is used incutting energy waste in buildings and data centers	3.43	.82	Agreed
10.	Predictive modelling techniques can forecast environmental changes	3.20	.65	Agreed
11.	AI aids in disaster preparedness and resource Management	3.22	.76	Agreed
12.	AI aids in mapping ocean plastic for clean-up operations	3.01	.74	Agreed
13.	Incorporating machine learning into environmental strategies can enhance decision-making processes	3.23	.77	Agreed
14.	AI is used in protecting wildlife from poaching	2.79	.81	Agreed
15.	AI can also be used to improve agriculture by reducing its environmental impact	2.94	.83	Agreed
16.	AI aids in energy conservation	3.25	.73	Agreed
17.	AI helps in pollution control, and waste management.	3.00	.94	Agreed
18.	AI aids in reducing water loss in cities the carbon cost of itself	3.46	.68	Agreed

N=111, Decision Rule =2.50, Cluster Mean and Standard Deviation 3.21and 0.74

With cluster mean of 3.21 and standard deviation of 0.74 all the items having mean scores above 2.50, results in table 5 revealed that lecturers agreed that AI is contributing on environmental management for sustainable development in Taraba State, Nigeria.

Hypotheses Testing

$H_{02:}$ There is no significant difference in the mean opinions of Federal Polytechnic Bali and Federal University Wukari lecturers on the contributions of AI on environmental management for sustainable development in Taraba State, Nigeria.

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Table 2: Computed Difference in the Mean ratings of Federal Polytechnic Bali and Federal University of Wukari Lecturers

Respondents	N	$\overline{X}$	SD	df	α	t-cal.	P-value level of significance	Remarks
Fed. Poly. Bali	128	3.29	0.78					
				222	0.05	1.36	1.96	Accepted
FUW		96	3.48	0.72				

Source: *Field Survey, (2026).*

Table 2 reveals the t-calculated value of 1.36 is less than the P-value of 1.96 at 0.05 level of significance and degree of freedom of 222. Thus, the null hypothesis of no significant difference in the mean ratings of Federal Polytechnic Bali and Federal University Wukari lectures on contributions of AI on environmental management for sustainable development in Taraba State, Nigeria was accepted.

Conclusion

The use of artificial intelligence (AI) can contribute to environmental management. AI can be used to improve agriculture and reduce its environmental impact. The role of AI in sustainable development and environmental impact includes AI's ability to fight against climate change; existing AI systems include tools that predict weather, track icebergs and identify pollution. The study concludes that connections between AI and environmental sustainability are emerging. Smart technology is being deployed in ecological monitoring, allowing for real-time data collection and analysis. Predictive modelling techniques can forecast environmental changes, aiding in disaster preparedness and resource management.

Recommendations

Based on the findings and conclusion of the study it was recommended that:

1. AI as an emerging technology should be used by farmers in predicting weather condition for improved agriculture and sustainable development.
2. AI-powered precision farming techniques should be used to enable farmers to monitor soil conditions, weather patterns, and crop health with unprecedented accuracy.

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