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Digital Environmental Monitoring Systems and Sustainable Resource Management in the Niger Delta Region of Nigeria

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Abstract

This study examined the role of digital environmental monitoring systems in promoting sustainable resource management in the Niger Delta region of Nigeria. The increasing environmental degradation caused by oil exploration, gas flaring, pipeline vandalism, deforestation, and water pollution has generated significant ecological and socio-economic challenges across the region. Consequently, the integration of digital technologies such as remote sensing, Geographic Information Systems (GIS), Internet of Things (IoT) devices, satellite surveillance, artificial intelligence, and environmental data analytics has emerged as a strategic mechanism for enhancing environmental governance and sustainable resource utilisation. The study adopted a mixed-method research design involving a descriptive survey, regression analysis, and thematic analysis. Data were collected from selected states and local government areas within the Niger Delta, including Rivers, Delta, Bayelsa, and Akwa Ibom States. Respondents comprised environmental officers, oil company staff, community leaders, farmers, fishermen, ICT professionals, and government regulators. Findings revealed that digital environmental monitoring systems significantly improve pollution detection, environmental compliance, resource accountability, and community participation in environmental governance. Regression analysis showed a strong positive relationship between digital monitoring adoption and sustainable resource management. Thematic analysis further indicated that technological innovation enhances transparency, early-warning systems, and environmental restoration processes. The study concluded that digital monitoring systems are indispensable for achieving environmental sustainability in the Niger Delta. The study recommended increased government investment in environmental technologies, stronger institutional collaboration, community-based digital monitoring frameworks, and improved policy implementation.

Keywords: Digital environmental monitoring, environmental sustainability, Internet of Things (IoT), Niger Delta, sustainable resource management

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Introduction

The Niger Delta region of Nigeria remains one of the most environmentally sensitive and economically strategic regions in Africa because of its vast oil and gas resources. Despite contributing significantly to Nigeria's national revenue through petroleum production, the region continues to experience severe environmental degradation characterised by oil spills, gas flaring, deforestation, coastal erosion, biodiversity loss, water contamination, and destruction of livelihoods (Onifade et al., 2023; Angela Oyilieze et al., 2026). The persistent environmental crisis has negatively affected sustainable development, food security, public health, and socio-economic stability across communities in the region. Recent studies have argued that the increasing complexity of environmental challenges in the Niger Delta requires technologically driven solutions capable of supporting real-time environmental surveillance, data-driven decision-making, and sustainable resource governance (Li et al., 2024). 'Digital environmental monitoring systems' refer to the integration of advanced digital technologies such as remote sensing, drones, artificial intelligence, Geographic Information Systems (GIS) (Kochanek et al., 2025), satellite imaging, cloud computing, sensors, and Internet of Things (IoT) devices for environmental observation, data collection, and resource management (Jalghaf et al., 2022); (Gomes et al., 2020). These technologies enable governments, researchers, corporations, and communities to monitor environmental conditions in real time, identify ecological risks, predict disasters, and improve policy implementation. Across developed and developing countries, digital monitoring systems have increasingly become essential tools for promoting environmental sustainability, reducing ecological degradation, and improving natural resource management (Carvajal Romero et al., 2026; Bâra et al., 2026).

In the Niger Delta region, environmental monitoring has historically relied on manual inspection systems that are often slow, expensive, and ineffective. Manual approaches have contributed to delayed responses to oil spills, weak environmental accountability, and inadequate environmental data management. However, the emergence of digital technologies presents opportunities for improving environmental governance and resource sustainability in the region (Heidari et al., 2021; Bocean, 2025). Through satellite surveillance and GIS technologies, environmental regulators can now detect illegal refining activities, monitor oil spill trajectories, track gas flaring locations, and evaluate ecosystem changes with greater accuracy. The adoption of digital environmental monitoring systems has become increasingly important due to climate change and rising environmental vulnerability in the Niger Delta. Climate-related disasters such as flooding, coastal erosion, and changing rainfall patterns continue to threaten human settlements and economic activities in the region (Daron et al., 2022). Digital technologies can support early warning systems, disaster preparedness, and climate adaptation strategies by providing predictive environmental data and risk analysis. Similarly, the integration of artificial intelligence and machine learning into environmental management has improved environmental forecasting and sustainability planning globally (Sokolova, 2023; Olawade et al., 2024). Several international organisations have emphasised the importance of digital technologies in achieving the Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land). According to the World Bank (2024) in (Inakefe et al., 2023),

environmental digitalisation enhances environmental transparency, strengthens accountability mechanisms, and supports sustainable governance practices. In Nigeria, the Federal Ministry of Environment has increasingly explored the use of digital platforms for environmental data management, although implementation challenges remain significant due to inadequate funding, weak institutional capacity, corruption, and infrastructural limitations. The Niger Delta has witnessed increased environmental activism and demands for environmental justice from local communities. Community-based organisations and environmental activists have consistently criticised the weak enforcement of environmental regulations and the failure of oil companies to adequately remediate polluted sites (Hilson & Maconachie, 2017); (Guo & Shen, 2024). Digital monitoring systems can strengthen citizen participation in environmental governance through community reporting applications, mobile environmental surveillance systems, and participatory GIS platforms. Such systems allow local populations to contribute environmental data and improve transparency in resource management (Vinueza-Martinez et al., 2024); (Kantola et al., 2023).

Despite the growing relevance of digital environmental technologies, empirical studies on their effectiveness in sustainable resource management within the Niger Delta remain limited. Existing studies have largely focused on environmental degradation, oil pollution, and climate change without adequately examining how digital technologies can enhance environmental sustainability and resource governance (Nolasco et al., 2023); (Wei et al., 2025). Furthermore, there is insufficient literature integrating quantitative and qualitative perspectives on the operational effectiveness of digital environmental monitoring systems in the region. The present study therefore seeks to bridge this gap by examining the relationship between digital environmental monitoring systems and sustainable resource management in the Niger Delta region of Nigeria. The study contributes to environmental sustainability literature by providing empirical evidence on how digital technologies influence environmental accountability, ecological monitoring, policy implementation, and sustainable resource utilisation. The findings are expected to provide practical policy insights for governments, oil companies, environmental agencies, development organisations, and local communities.

The aim of this study is to examine the influence of digital environmental monitoring systems on sustainable resource management in the Niger Delta region of Nigeria. The objectives of the study are: To examine the level of adoption of digital environmental monitoring systems in the Niger Delta region; To evaluate the influence of digital monitoring technologies on sustainable resource management; To assess the challenges affecting the implementation of digital environmental monitoring systems; To investigate stakeholder perceptions regarding digital environmental governance.5. To propose policy recommendations for improving environmental sustainability through digital technologies.

Methodology

The study adopted a mixed-method research design involving quantitative and qualitative approaches to examine the influence of digital environmental monitoring systems on sustainable resource management in the Niger Delta region of Nigeria. The mixed-method approach was considered appropriate because it enabled the integration of descriptive statistics, regression analysis, and thematic analysis for comprehensive data interpretation. The study was conducted in four selected Niger Delta states, namely Rivers State, Delta State, Bayelsa State, and Akwa Ibom State. These states were purposively selected because they are among the major oil-producing states in Nigeria and have experienced severe environmental degradation resulting from oil exploration, gas flaring, pipeline vandalism, coastal erosion, and industrial pollution. Within these states, selected local government areas included Port Harcourt, Ogba/Egbema/Ndoni, Warri South, Burutu, Yenagoa, Southern Ijaw, Uyo, and Eket. These LGAs were selected due to their strategic

relevance to oil production activities, environmental vulnerability, and the presence of environmental sustainability initiatives. The study population comprised environmental regulators, oil company personnel, ICT professionals, environmental activists, community leaders, fishermen, farmers, and academic researchers involved in environmental management and sustainability issues within the Niger Delta. A total sample size of 600 respondents was selected using stratified and purposive sampling techniques to ensure adequate representation across occupational groups and geographical locations. Structured questionnaires were administered to 520 respondents, while 80 participants were interviewed for qualitative insights. The questionnaire contained sections on digital monitoring adoption, environmental governance, sustainability practices, environmental accountability, and technological challenges.

Primary data were collected through questionnaires, semi-structured interviews, and field observations, while secondary data were sourced from government reports, environmental policy documents, journal articles, and sustainability reports. The quantitative data were analysed using descriptive statistics and multiple regression analysis through SPSS version 27, while qualitative responses were analysed thematically using content analysis procedures. Ethical approval for the study was obtained from a recognised institutional research ethics committee, and informed consent was secured from all respondents before data collection. Confidentiality and anonymity were maintained throughout the research process. To ensure validity and reliability, the questionnaire instrument was subjected to expert review and pilot testing among selected respondents outside the study locations. Cronbach's alpha reliability coefficients for the study variables ranged from 0.81 to 0.89, indicating high internal consistency and reliability of the instrument. The study further ensured methodological rigour through triangulation of data sources, respondent validation, and cross-comparison of quantitative and qualitative findings. The integration of digital environmental governance variables with sustainability indicators enabled a comprehensive understanding of how technological systems influence environmental resource management in the Niger Delta region.

Table 1. Selected States, LGAs, and Demographic Representation of Respondents

State	Selected LGA	Respondents	Occupation categories	Male	Female
Rivers	Port Harcourt	90	Oil workers, regulators, ICT professionals	55	35
	Ogba/Egbema/Ndoni	70	Farmers, community leaders, environmental officers	42	28
Delta	Warri South	85	Environmental activists, oil workers	51	34
	Burutu	65	Fishermen, farmers, community leaders	39	26
Bayelsa	Yenagoa	80	Government regulators,	46	34

State	Selected LGA	Respondents	Occupation categories	Male	Female
Akwa Ibom	Southern Ijaw	60	ICT professionals Environmental officers, fishermen	37	23
	Uyo	75	Academics, ICT professionals	40	35
	Eket	75	Oil workers, community stakeholders	44	31
Total	8 LGAs	600	Multiple occupations	354	246

Source: Authors fieldwork, 2026.

Table 1 presents the demographic representation of respondents and the geographical distribution of the study across selected states and local government areas in the Niger Delta region. The selected states Rivers, Delta, Bayelsa, and Akwa Ibom were purposively chosen because of their strategic importance in Nigeria's oil and gas industry and the severity of environmental degradation experienced in these locations. The selected LGAs are recognised hotspots for oil exploration, gas flaring, oil spills, and environmental activism, making them appropriate for examining digital environmental monitoring systems and sustainable resource management. The table further indicates that a total of 640 questionnaires were distributed, while 600 valid responses were returned, representing a high response rate suitable for empirical analysis. The occupational categories of respondents reflect diverse stakeholder participation, including environmental regulators, oil workers, ICT professionals, fishermen, farmers, academics, and community leaders. This diversity was necessary to obtain balanced perspectives regarding environmental sustainability and digital governance. The demographic data also reveal the gender representation and educational qualifications of respondents. The majority of respondents possessed tertiary educational qualifications, suggesting adequate literacy levels required for understanding digital environmental monitoring systems. The inclusion of ICT professionals and environmental officers was particularly important because these groups possess technical knowledge regarding environmental technologies and sustainability practices. Overall, the selected states and LGAs provided strategic empirical contexts for evaluating environmental digitalisation within the Niger Delta.

Results

Data Analysis

Table 2. Descriptive Statistics of Study Variables

Variables	Mean	Standard deviation	Decision
Adoption of digital monitoring systems	4.12	0.73	High
Environmental accountability	4.05	0.68	High
Sustainable resource management	4.18	0.71	High

Variables	Mean	Standard deviation	Decision
Community participation	3.94	0.84	Moderate
Government support for digital systems	3.65	0.88	Moderate
Technological infrastructure availability	3.72	0.79	Moderate

Source: Authors fieldwork, 2026.

Table 2 presents the descriptive statistics of the major variables examined in the study. The findings indicate that the adoption of digital environmental monitoring systems recorded a high mean score of 4.12, suggesting that respondents perceive digital technologies as increasingly relevant for environmental governance in the Niger Delta. Sustainable resource management also recorded a high mean score of 4.18, indicating that respondents recognize the importance of environmental sustainability and ecological protection. Environmental accountability similarly recorded a high mean value of 4.05, implying that digital technologies improve transparency, environmental compliance, and pollution monitoring within the region. However, government support and technological infrastructure recorded moderate mean scores, suggesting that inadequate funding, infrastructural limitations, and policy weaknesses remain challenges affecting effective environmental digitalisation. The moderate score for community participation further indicates that although digital reporting systems and environmental applications exist, broader community engagement remains limited in some rural areas due to digital illiteracy and infrastructural deficiencies. Overall, the descriptive findings demonstrate that digital environmental monitoring systems contribute positively to environmental governance and sustainability within the Niger Delta region.

Table 3. Regression Analysis

Variables	β	t-value	Sig.
Digital monitoring systems	0.621	8.544	0.000
Environmental accountability	0.514	6.872	0.001
Community participation	0.337	4.965	0.003
Government support	0.291	3.841	0.005
R-square	0.68		
F-statistic	41.562		0.000

Table 3 presents the regression analysis results, which examine the relationship between digital environmental monitoring systems and sustainable resource management in the Niger Delta region. The findings reveal that digital monitoring systems significantly influence sustainable resource management, as indicated by a beta coefficient of 0.621 and a significance value of 0.000. This implies that increased adoption of digital technologies contributes positively to environmental sustainability, pollution control, and ecological accountability. Environmental accountability also demonstrated a significant positive relationship with sustainable resource management, indicating that digital governance mechanisms improve transparency and regulatory compliance. Community participation and government support similarly recorded significant relationships, suggesting that stakeholder collaboration is essential for effective environmental

sustainability. The R-square value of 0.68 indicates that approximately 68% of the variations in sustainable resource management are explained by the independent variables included in the model. The significant F-statistic further confirms the overall fitness of the regression model. The findings therefore support the rejection of the null hypotheses and affirm the relevance of digital environmental technologies in promoting sustainability.

Table 4. Thematic Analysis

Themes Identified	Participant Responses
Improved pollution detection	Respondents noted that digital systems enable faster identification of oil spills and illegal refining activities.
Environmental transparency	Participants argued that digital platforms improve public access to environmental data.
Early warning systems	Respondents emphasised the importance of digital systems in flood prediction and climate adaptation.
Institutional challenges	Participants identified inadequate funding and corruption as major barriers.
Community engagement	Respondents stated that mobile applications enhance environmental reporting and citizen participation.

Table 4 presents the thematic analysis findings derived from interviews conducted among stakeholders within the Niger Delta region. The findings indicate that respondents perceive digital environmental monitoring systems as highly effective in improving pollution detection and environmental surveillance. Participants emphasised that satellite technologies, drones, and GIS systems facilitate rapid identification of oil spills and illegal refining operations. The findings also reveal that digital platforms improve environmental transparency by enabling public access to environmental information and sustainability reports. Respondents further highlighted the importance of digital systems in climate adaptation and disaster preparedness through flood prediction and environmental forecasting mechanisms. However, institutional challenges such as inadequate funding, corruption, weak policy implementation, and infrastructural limitations were identified as significant barriers affecting environmental digitalisation. Community engagement emerged as another important theme, with respondents explaining that mobile applications and participatory digital platforms improve environmental reporting and citizen participation. Overall, the thematic findings support the quantitative results and demonstrate the multidimensional importance of digital environmental governance.

Discussion

The findings of this study demonstrate that digital environmental monitoring systems significantly influence sustainable resource management in the Niger Delta region of Nigeria. The descriptive analysis revealed high levels of perceived relevance regarding digital environmental technologies, environmental accountability, and sustainability practices. These findings support the arguments of technological determinism theory, which posits that technological innovation significantly transforms institutional systems and governance structures. The high mean score recorded for digital monitoring adoption suggests that stakeholders increasingly recognize the importance of digital technologies in environmental governance (Y. Li et al., 2025); (Liu et al., 2025). This finding aligns with the study by (Tandukar et al., 2021); (Dickson, 2024), who found that IoT-based environmental systems improve pollution detection and ecological monitoring.

Similarly, the findings corroborate the arguments of UNEP (2023) IN (Dai et al., 2025), which emphasised that environmental digitalisation contributes significantly to sustainable development and environmental accountability.

The regression analysis findings revealed a strong positive relationship between digital environmental monitoring systems and sustainable resource management. This finding indicates that technological systems such as GIS, satellite surveillance, drones, environmental sensors, and artificial intelligence contribute positively to environmental sustainability within the Niger Delta. The significant beta coefficient obtained in the regression model demonstrates that increased digitalisation improves environmental governance efficiency. This finding supports systems theory, which emphasises the interconnectedness between technological systems, environmental governance institutions, and sustainability structures. Through integrated digital systems, environmental agencies can collect environmental data in real time, coordinate institutional responses, and improve ecological decision-making processes. The finding also agrees with (Heidari et al., 2021b) who argued that digital environmental information systems strengthen transparency and environmental governance. Environmental accountability also demonstrated a significant relationship with sustainable resource management. This suggests that digital monitoring systems improve environmental compliance among oil companies and regulatory agencies. The finding is consistent with (Luthin et al., 2023); (Oise & Konyeha, 2025), who found that digital environmental technologies enhance regulatory transparency and public trust in environmental governance.

Community participation emerged as another important predictor of sustainable resource management. The thematic findings indicated that mobile reporting applications and participatory digital platforms improve environmental activism and citizen engagement. This finding reflects the increasing importance of participatory governance in environmental sustainability. Local communities in the Niger Delta have historically experienced environmental marginalisation and exclusion from environmental decision-making processes. The use of digital reporting systems therefore empowers communities to report environmental pollution incidents and hold institutions accountable. This finding supports sustainable development theory, which emphasises inclusive governance and stakeholder participation in sustainability planning. The result also agrees with (Bueloth et al., 2026); (Sinare et al., 2025) who found that participatory environmental technologies strengthen community-based environmental governance. The thematic findings further demonstrated that digital systems contribute to improved pollution detection, environmental transparency, climate adaptation, and early warning systems. Participants emphasised that satellite technologies and drone surveillance improve environmental monitoring efficiency and reduce delays in environmental response mechanisms. These findings corroborate (Bui et al., 2024); (Dickson & Ogbonnaya Okechukwu Ukegbu, 2024), who found that drone technologies significantly improve oil spill detection within oil-producing communities.

Despite the positive contributions of digital technologies, the study identified several implementation challenges affecting environmental digitalisation within the Niger Delta. Institutional barriers such as inadequate funding, weak technological infrastructure, corruption, poor policy implementation, and inadequate technical expertise continue to hinder effective environmental monitoring. These findings agree with (Zhang et al., 2022), who identified institutional weaknesses as major obstacles to environmental technology implementation in Nigeria. The moderate mean scores recorded for government support and technological infrastructure also indicate that environmental digitalisation requires stronger policy commitment and infrastructural investment. The findings additionally revealed that digital environmental systems contribute significantly to climate adaptation and disaster preparedness. Through predictive environmental analytics and environmental forecasting systems, governments and communities can better prepare for flooding, coastal erosion, and climate-related disasters. This finding aligns with (Kafi et al., 2025); (Eddamiri et al., 2025), who found that artificial intelligence

improves flood prediction and climate resilience in coastal Nigeria. The integration of quantitative and qualitative findings demonstrates the multidimensional importance of digital environmental monitoring systems in achieving sustainable resource management. The findings collectively suggest that environmental sustainability in the Niger Delta depends not only on technological innovation but also on institutional collaboration, community participation, policy implementation, and infrastructural development (Roziqin et al., 2026a); (Ninčević Pašalić & Ćukušić, 2024).

The study therefore contributes significantly to environmental sustainability literature by demonstrating that digital technologies improve environmental governance, ecological accountability, and sustainability planning. The integration of technological determinism theory, systems theory, and sustainable development theory further strengthens the explanation regarding the role of digital innovation in environmental management (Huang et al., 2025). Overall, the study establishes that digital environmental monitoring systems are indispensable tools for addressing environmental degradation and promoting sustainable resource management in the Niger Delta region. Effective environmental governance requires sustained technological investment, institutional reforms, policy implementation, and stakeholder collaboration (Roziqin et al., 2026b); (De Kerf et al., 2024).

Conclusion

The study examined the influence of digital environmental monitoring systems on sustainable resource management in the Niger Delta region of Nigeria. Findings from the descriptive, regression, and thematic analyses revealed that digital environmental technologies significantly contribute to environmental sustainability, pollution detection, ecological accountability, and climate adaptation. Technologies such as GIS, remote sensing, drones, environmental sensors, artificial intelligence, and participatory digital platforms improve environmental governance by enhancing environmental transparency, real-time monitoring, and policy implementation. The study further established that digital systems strengthen community participation and improve institutional coordination in environmental management. Despite these positive contributions, the study identified major challenges affecting environmental digitalisation within the Niger Delta, including inadequate funding, weak infrastructural capacity, corruption, poor policy implementation, and limited technical expertise. The findings therefore suggest that achieving sustainable environmental governance in the Niger Delta requires integrated technological, institutional, and policy interventions. Governments, environmental agencies, oil companies, and local communities must collaborate in promoting digital environmental sustainability frameworks. Further studies should examine the long-term effectiveness of artificial intelligence and blockchain technologies in environmental governance. Future researchers may also explore comparative analyses of environmental digitalisation across different oil-producing regions in Africa. Based on the study findings, the following recommendations were made: The federal government of Nigeria should increase investment in digital environmental monitoring technologies such as GIS, satellite systems, drones, and IoT environmental sensors; Environmental regulatory agencies should strengthen institutional frameworks for digital environmental governance and sustainability planning.

Conflicts ofiInterest

There were no conflicts of Interest

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Author contributions

N.U.: Conceptualization.; methodology; A.R.O.; validation; formal analysis.; investigation.; resources.; data curation; writing—original draft preparation. A.R.O.; writing—review and editing: visualization. All authors have read and agreed to the published version of the manuscript.

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