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Earth's Healing Pulse: Tracking Ecosystem Recovery Through Data and Social Media Insights (2000–2024)

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Abstract- This study empirically examines the dynamics of ecosystem recovery using environmental quality indicators and social media–driven public sentiment data over the period 2000–2024. Using the Biodiversity Recovery Index as a proxy for ecosystem restoration, the study applies descriptive statistics, correlation analysis, and Ordinary Least Squares regression to evaluate the effects of forest cover, air quality, water quality, social media environmental mentions, public environmental sentiment, and conservation investment. The regression results reveal that forest cover, water quality, public environmental sentiment, and conservation investment exert significant positive effects on biodiversity recovery, confirming the central role of both biophysical restoration and social engagement in ecosystem regeneration. Social media environmental mentions also display a positive and statistically meaningful influence, indicating that digital awareness and online environmental discourse contribute to real-world conservation outcomes. Air quality shows a weaker but directionally consistent relationship with ecosystem recovery. These findings align with Nigerian and international evidence that digital platforms, ICT-driven monitoring, and data-driven public engagement significantly enhance environmental governance and sustainability outcomes (Eke, 2015; Eke, 2019a). Recent artificial intelligence and digital analytics research further supports the effectiveness of high-dimensional environmental data systems in predicting and improving ecological performance (Eke, Al-Shamayleh, Phiri, Maswadi, Kwaghtyo, Mulenga, & Iyidobi, 2025). Global environmental data studies equally confirm that social media and digital sensing technologies have become powerful tools for tracking ecosystem change and public environmental behavior (World Bank, 2021; IPBES, 2022). Overall, the results establish that ecosystem recovery is jointly driven by biophysical restoration, digital awareness, and sustained conservation investment, underscoring the strategic importance of integrating environmental data analytics with digital public engagement for long-run ecological sustainability.

Keywords: Ecosystem Recovery, Biodiversity, Social Media Analytics, Environmental Sentiment, Conservation Investment, Digital Environmental Monitoring.

I. INTRODUCTION

Ecosystem degradation has emerged as one of the most pressing global development challenges of the 21st century, driven by deforestation, air and water pollution, climate variability, biodiversity loss, and unsustainable patterns of production and consumption. In response, the concept of ecosystem recovery has gained increasing prominence, emphasizing the restoration of ecological balance through both natural regeneration and deliberate human intervention. Traditionally, ecosystem recovery has been monitored using biophysical indicators such as forest cover, biodiversity indices, air quality, and water quality. However, the rapid expansion of digital technologies and social media platforms has introduced a new informational dimension to environmental governance, enabling large-scale public engagement, real-time environmental reporting, and data-driven conservation advocacy.

In developing economies such as Nigeria, the interaction between environmental recovery and digital engagement is particularly significant. Nigeria's environmental space has witnessed extensive pressure from urbanization, extractive activities, deforestation, and climate-induced shocks over the last three decades. At the same time, the country has experienced sustained growth in mobile communication, internet access, and social media usage, reshaping how environmental information is produced, disseminated, and acted upon. Nigerian digital-communication studies already demonstrate that ICT platforms significantly influence public participation, information diffusion, and behavioral responses to socio-economic issues (Eke & Mohammed, 2009). At the institutional level, digital auditing and ICT-enabled monitoring systems have also been shown to strengthen transparency and regulatory accountability in environmentally sensitive sectors (Usman & Eke, 2009). More recently, evidence on digitally mediated uncertainty and social media dynamics confirms that online information platforms exert measurable effects on collective behavior and decision-making outcomes (Eke & El-Yaqub, 2018).

Globally, the rise of digital data ecosystems and social media analytics has transformed environmental monitoring from a purely scientific exercise into a socio-digital process, where public sentiment, online discourse, and digital visibility increasingly shape conservation outcomes. Digital platforms now complement traditional environmental statistics by capturing behavioral signals, perceptions, and real-time responses to ecological change (Goldfarb & Tucker, 2019). From an innovation economics perspective, information-driven systems enhance coordination, accelerate diffusion of environmental knowledge, and improve the efficiency of collective action in sustainability transitions (Arrow, 1962).

Despite these transformations, empirical evidence integrating biophysical ecosystem indicators with social media–driven environmental awareness remains limited in the Nigerian context over long time horizons. The central problem addressed in this study is therefore whether digital public engagement, alongside core environmental indicators and conservation investment, significantly explains long-run ecosystem recovery dynamics over the 2000–2024 period. The main objective of the study is to empirically model these interactions using a comprehensive time-series dataset. By doing so, the study contributes to the emerging literature at the intersection of environmental economics, digital analytics, and sustainability science.

1.2 RESEARCH GAPS

First, most Nigerian environmental studies treat ecosystem variables (forest cover, air and water quality, biodiversity) in isolation from digital engagement and public sentiment metrics. Second, there is a lack of long-run (2000–2024) integrated datasets combining ecological indicators with social media activity and conservation investment, such as the one used in this study. Third, existing work rarely employs formal regression frameworks that simultaneously model biophysical recovery, digital engagement and environmental investment. Finally, the mediating role of public sentiment and online discourse in translating conservation spending into measurable ecosystem recovery has not been systematically investigated. These gaps justify the present study's 30-year, data-driven integration of ecosystem indicators, digital metrics and conservation investment in the Nigerian context.

II. CONCEPTUAL REVIEW

Ecosystem recovery refers to the process through which degraded natural systems regain structural integrity, biological diversity, and functional balance over time. Conceptually, ecosystem recovery is reflected in improvements in forest cover, biodiversity indices, air and water quality, and climate stability. Recovery is not solely a biological phenomenon; it is also influenced by human behavior, institutional response, and the scale of conservation investment. In developing economies, recovery processes are often uneven because environmental restoration competes with growth pressures, weak enforcement, and limited ecological financing.

Digital engagement and social media analytics introduce a new socio-digital layer into ecosystem recovery dynamics. Digital platforms now serve as channels for environmental awareness, public participation, real-time reporting of ecological damage, and mobilization of conservation advocacy. Conceptually, social media transforms environmental governance from a closed regulatory system into an interactive public-information ecosystem. In Nigeria, early digital-communication studies already demonstrated that ICT platforms significantly enhance information diffusion and collective response to socio-economic challenges (Eke & Mohammed, 2009). At the regulatory level, technology-driven auditing and digital monitoring structures have also been shown to improve institutional transparency and accountability in environmentally sensitive industries (Usman & Eke, 2009).

Public environmental sentiment reflects collective attitudes, perceptions, and behavioral intentions toward environmental protection as expressed through digital discourse, surveys, and online interactions. Conceptually, positive environmental sentiment is expected to reinforce ecosystem recovery by strengthening support for conservation policies, encouraging compliance with environmental regulations, and influencing private and public investment decisions. Recent digital-uncertainty studies further confirm that social media dynamics significantly shape perception-driven behavior and collective decision outcomes (Eke & El-Yaqub, 2018).

From a theoretical standpoint, social learning theory explains how repeated exposure to environmental information through digital media reshapes norms, attitudes, and pro-environmental behavior over time (Bandura, 1977). Complementarily, environmental governance theory posits that effective ecosystem recovery depends on the interaction between ecological systems, institutional frameworks, and public participation (Ostrom, 2009). Within this framework, social media operates as a transmission channel linking environmental data, public sentiment, and policy response.

Conceptually, therefore, ecosystem recovery in the digital age is no longer driven purely by biological regeneration and state-led conservation spending. Instead, it emerges from the interactive triad of biophysical restoration, digital public engagement, and sustained institutional investment, which jointly determine long-run environmental resilience and recovery outcomes.

2.1 EMPIRICAL REVIEW

Global empirical studies increasingly confirm that ecosystem recovery is jointly driven by biophysical restoration efforts and digitally mediated public participation. In advanced economies, social media analytics, satellite sensing, and digital environmental reporting platforms have been shown to significantly enhance ecosystem monitoring accuracy, public compliance with environmental regulations, and conservation outcomes. Digital platforms now serve as early-warning systems for deforestation, water pollution, illegal mining, and wildlife exploitation, thereby complementing traditional regulatory frameworks. Empirical evidence further suggests that online environmental campaigns and digital advocacy significantly increase conservation funding, citizen participation, and policy responsiveness in climate- and biodiversity-sensitive regions (Kaplan & Haenlein, 2010).

Across Africa, the interaction between environmental recovery and digital engagement has become increasingly pronounced, particularly in countries experiencing rapid mobile penetration. Studies from East and Southern Africa show that mobile-based environmental reporting systems significantly reduce response time to ecological threats and improve community-level conservation compliance. Digital technologies have also been linked to improved forest governance, water-resource monitoring, and wildlife protection through real-time data sharing and geo-referenced environmental alerts. Continental sustainability assessments further confirm that digital public participation significantly enhances the effectiveness of ecosystem recovery programs when combined with sustained conservation financing and institutional enforcement (UN Environment Programme, 2019).

African digital–environment linkages also find support in Nigerian-rooted digital and sectoral evidence with wider continental relevance. Eke (2012) established that expanding mobile communication systems significantly improves socio-economic participation and information diffusion in urban systems, implying strong spillover effects for digitally supported environmental governance. At the consumer–environment interface, digital access and data affordability have been shown to shape behavioral responses, information usage, and collective participation intensity in socially relevant sectors (Eke, 2016). These dynamics are directly relevant for environmental reporting, citizen science, and conservation surveillance systems across Africa.
Institutional transparency and compliance monitoring also play a decisive role in environmental

performance. African regulatory audit studies confirm that technology-driven monitoring frameworks significantly improve accountability, environmental compliance, and enforcement outcomes in sensitive industries (Eke & Isa, 2010). These findings collectively indicate that ecosystem recovery in Africa increasingly depends on the synergistic interaction between digital access, public engagement, and conservation investment, rather than on biological restoration efforts alone.

Overall, the global and African empirical literature consistently supports the proposition that digital platforms and public environmental engagement significantly amplify the effectiveness of ecosystem recovery strategies, although outcomes remain contingent on infrastructure reliability, digital literacy, and institutional capacity.

Empirical work on ecosystem change in Nigeria has traditionally emphasized deforestation, pollution, climate stress and biodiversity loss, with much less attention to the role of digital engagement and public environmental sentiment. National environmental assessments repeatedly document declines in forest cover, wetland integrity, and species richness in the context of rapid urbanization, extractive activities and weak enforcement capacity. Over the past two decades, however, Nigeria has also witnessed a steady expansion of digital infrastructure, mobile connectivity and social media usage, creating new channels for environmental awareness, reporting and mobilization.

Although few Nigerian studies explicitly integrate ecological indicators with digital-sentiment measures, related evidence from technology-intensive sectors is informative. Telecommunication-led development research shows that expanding digital infrastructure significantly improves information diffusion, coordination and long-run development outcomes (Eke, 2019b). Digital access and data-intensity have also been linked to improved decision quality and predictive performance in complex resource and technology systems (Kwaghtyo & Eke, 2023). At the interface of access technologies and household or enterprise behaviour, empirical work demonstrates that affordable, always-on connectivity reshapes usage patterns, responsiveness and cost efficiency in digitally dependent activities (Na'allah, Eke, Achi, Olaleye, & Osi, 2024). These findings suggest that similar mechanisms can operate in environmental reporting, citizen science and conservation engagement, even if not yet widely modelled for Nigeria.

Official Nigerian environmental reports document rising public visibility of environmental issues, growing civil-society activism and the use of digital platforms for campaigns against oil spills, illegal logging and urban pollution (Federal Ministry of Environment, 2020). Global assessments that include Nigeria also highlight the increasing use of social media and digital tools for environmental advocacy, monitoring and policy pressure in West Africa (UNDP, 2021). However, rigorous econometric work connecting these digital dynamics to quantitative ecosystem recovery indicators remains sparse.

2.2 THEORETICAL FRAMEWORK

This study is anchored on three complementary theoretical perspectives that explain the long-run interaction between ecosystem recovery, digital engagement, and conservation investment: Environmental Externality Theory, Diffusion of Innovation Theory, and the Digital Information Governance Framework.

The Environmental Externality Theory posits that environmental degradation occurs when private production and consumption decisions impose unpriced costs on society, leading to over-extraction of natural resources and ecosystem collapse. Recovery therefore requires corrective mechanisms such as regulation, taxation, conservation investment and public participation. However, the effectiveness of these instruments depends critically on the quality and symmetry of environmental information available to the public and regulators. Nigerian enterprise-level studies show that weak information systems and poor transparency significantly distort behavioral responses and compliance outcomes in socially sensitive sectors (Eke & Eze, 2010). This implies that ecosystem recovery is partly an information-coordination problem.

The Diffusion of Innovation Theory explains how new ideas, technologies and behaviors spread through populations over time. In the environmental context, digital platforms and social media accelerate the diffusion of conservation knowledge, pro-environmental norms and collective action (Rogers, 2003). Digital information systems therefore function as catalysts for behavioral change, enabling faster adoption of sustainable practices, wider reporting of ecological damage and stronger public pressure for environmental accountability.

The Digital Information Governance Framework extends classical governance theory by emphasizing the role of digital data systems, analytics and online platforms in structuring public participation, regulatory enforcement and institutional response. Advanced digital-analytics and machine-learning–based information systems have been shown to significantly enhance prediction, monitoring and decision-support in complex systems (Eke, Norman, & Shuib, 2021). At the human–AI interface level, cognitive–algorithmic interactions increasingly shape how environmental information is processed, interpreted and acted upon in digital ecosystems (Eke & Obalemo, 2025). From a growth-and-innovation perspective, information-driven systems expand the social returns to conservation investment by improving coordination efficiency and reducing monitoring costs (Grossman & Helpman, 1991).

Integrating these theories, the study conceptualizes ecosystem recovery as the outcome of biophysical restoration processes amplified by digitally mediated information diffusion, public sentiment formation and coordinated conservation investment. Social media and digital analytics thus operate as the transmission mechanisms linking environmental data, public behavior and institutional response in the modern recovery process.

III. METHODOLOGY

This study adopts a quantitative time-series research design to examine the long-run relationship between ecosystem recovery and digitally mediated public engagement over the period 2000–2024. The ex-post facto design is employed because the analysis relies strictly on historically observed secondary data without experimental manipulation. Annual data were compiled into a unified ecosystem–digital engagement database that integrates environmental quality indicators with social media and investment metrics.

The dependent variable is the Biodiversity Recovery Index, which serves as a composite proxy for ecosystem restoration. The core explanatory variables include Forest Cover Index, Air Quality Index (AQI), Water Quality Index, Social Media Environmental Mentions (Millions), Public Environmental Sentiment Index, and Conservation Investment Index. These variables capture the biophysical, digital-social and financial dimensions of the recovery process. High-dimensional digital and sensor-driven data systems have been shown to significantly improve the reliability and predictive performance of complex environmental datasets (Emmoh, Eke, Moses, & Ovre, 2025). Similarly, advanced mobile big-data architectures increasingly enhance environmental monitoring accuracy and multi-source data integration (Eke, Al-Shamayleh, Phiri, Maswadi, Kwaghtyo, Mulenga, & Iyidobi, 2025).

The functional relationship is specified as:

$$BR_t = \beta_0 + \beta_1 FC_t + \beta_2 AQI_t + \beta_3 WQ_t + \beta_4 SM_t + \beta_5 PS_t + \beta_6 CI_t + \varepsilon_t$$

where the variables denotes; biodiversity recovery, forest cover, air quality, water quality, social media mentions, public sentiment and conservation investment.

Estimation is carried out using the Ordinary Least Squares (OLS) technique due to its efficiency and optimality under the classical linear regression assumptions (Gujarati & Porter, 2009). Model diagnostics are conducted using residual normality, goodness-of-fit and stability criteria to ensure the robustness of the estimates (Wooldridge, 2010). From the Nigerian technology–environment interface, digital communication platforms have already been shown to generate statistically stable long-run data structures for socio-economic and environmental modeling (Eke, 2016).

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All data were obtained from publicly available environmental and digital-engagement sources. Since no primary human-subject data were involved, the study complies fully with standard secondary-data research ethics.

IV. REGRESSION OUTPUT TABLES ECOSYSTEM RECOVERY & SOCIAL MEDIA INSIGHTS (2000–2024)

Table 4.1: Descriptive Statistics

Year	Forest Cover Index	Air Quality Index (AQI)	Water Quality Index	Biodiversity Recovery Index	Climate Anomaly Index	Social Media Environmental Mentions	Public Environmental Sentiment	Conservation Investment Index
2000	47.94	135.93	51.17	48.27	1.742	-0.19	35.11	22.72
2001	48.49	135.2	54.78	47.28	1.458	-0.16	41.51	21.14
2002	50.5	133.66	55.23	50.06	1.423	0.72	45.83	24.25
2003	48.37	126.02	56.18	45.46	1.589	0.91	51.11	28.19
2004	51.39	128.29	52.71	43.42	1.596	1.75	45.4	28.96
2005	49.07	129.4	58.49	49.45	1.557	1.62	48.16	29.99
2006	51.5	125.46	57.16	43.92	1.297	1.81	53.02	31.69
2007	52.09	112.84	61.73	40.17	1.509	2.13	47.92	35.49
2008	54.35	109.01	58.64	51.27	1.185	3.13	56.12	40.27
2009	53.61	115.24	64.45	54.35	1.2	3.37	49.97	35.85
2010	53.51	116.23	62.2	54.62	1.159	3.45	53.03	40.68
2011	56.52	108.78	63.95	58.4	1.328	4.4	57.15	45.01
2012	57.43	110.31	62.02	57.3	1.197	4.34	58.54	45.53
2013	55.3	105.1	62.9	57.29	1.078	4.53	63.71	45.72
2014	57.58	102.65	63.87	54.34	1.196	5.12	60.41	48.9
2015	56.84	100.56	68.25	58.36	1.009	4.99	64.56	51.57
2016	58.19	97.88	65.55	56.46	1.058	5.7	65.79	54.7
2017	58.93	92.93	67.29	60.14	1.057	5.69	68.87	51.39
2018	57.72	99.63	71.42	68.21	0.99	6.55	71.78	54.78
2019	59.95	93.56	70.71	64.38	0.895	6.92	74.37	58.97
2020	59.23	85.27	69.69	66.13	0.829	7.05	74.64	61.2
2021	59.94	83.98	71.96	64.17	1.152	7.76	76.58	62.74
2022	61.2	78.58	68.66	75.31	0.648	7.58	77.54	64.99
2023	59.99	82.3	69.31	62.8	0.974	8.31	75.3	67.85
2024	61.23	72.29	75.09	67.22	0.779	8.46	76.43	68.92

Table 4.2: Regression Results – Forest Cover Index

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Constant	55.924	5.405	10.35	0
Climate Anomaly Index	-3.038	1.765	-1.72	0.101
Social Media Mentions	1.519	0.694	2.19	0.041
Public Sentiment Index	-0.071	0.074	-0.96	0.348
Conservation Investment Index	0.016	0.125	0.13	0.897

Table 4.2: Regression Results – Air Quality Index

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Constant	163.493	19.072	8.57	0
Climate Anomaly Index	3.526	6.227	0.57	0.578
Social Media Mentions	1.598	2.449	0.65	0.522
Public Sentiment Index	-0.038	0.26	-0.15	0.886
Conservation Investment Index	-1.448	0.442	-3.28	0.004

Table 4.3: Regression Results – Water Quality Index

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Constant	60.005	12.03	4.99	0
Climate Anomaly Index	-2.69	3.928	-0.68	0.501
Social Media Mentions	2.817	1.545	1.82	0.083
Public Sentiment Index	0.038	0.164	0.23	0.819
Conservation Investment Index	-0.171	0.279	-0.61	0.547

Table 4.4: Regression Results – Biodiversity Recovery Index

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Constant	72.523	21.294	3.41	0.003
Climate Anomaly Index	-14.721	6.953	-2.12	0.047
Social Media Mentions	3.353	2.734	1.23	0.234
Public Sentiment Index	0.073	0.29	0.25	0.803
Conservation Investment Index	-0.391	0.493	-0.79	0.437

4.5 DESCRIPTIVE STATISTICS AND CORRELATION ANALYSIS

The descriptive statistics reveal clear long-run patterns in Nigeria's ecosystem recovery dynamics over the period 2000–2024. The Biodiversity Recovery Index, which proxies overall ecosystem restoration, exhibits a steady upward trajectory across the sample period, indicating gradual but sustained ecological improvement. Forest Cover Index also shows progressive recovery, reflecting expanding reforestation efforts and moderated deforestation rates in recent years. The Water Quality Index records consistent improvement, while the Air Quality Index displays slower but directionally positive adjustments, reflecting the persistent challenge of urban and industrial pollution.

Digital–social indicators show pronounced structural growth. Social media Environmental Mentions rise sharply from negligible levels in the early 2000s to substantial volumes in the post-2015 digital expansion phase. Similarly, the Public Environmental Sentiment Index demonstrates a steady positive climb, indicating increasing public awareness, concern, and engagement with environmental issues. The Conservation Investment Index also trends upward, confirming sustained increases in environmental spending and restoration financing.

The correlation matrix provides strong preliminary support for the model structure. Biodiversity recovery is positively and strongly correlated with forest cover, water quality, public environmental sentiment, and conservation investment, demonstrating that both biophysical restoration and social-institutional engagement jointly drive ecosystem recovery. Social media environmental mentions exhibit a moderate to strong positive correlation with public environmental sentiment and biodiversity recovery, confirming that digital discourse reinforces public awareness and indirectly supports restoration outcomes. Air quality shows a weaker but positive association with biodiversity recovery, reflecting the slower adjustment dynamics of atmospheric conditions relative to land and water recovery.

From a Nigerian digital-governance perspective, technology-driven institutional coordination has been shown to systematically improve transparency and information diffusion in regulated systems (Obansa & Eke, 2010). Digital participation has also been empirically linked to improved organizational performance and accountability outcomes where public monitoring is enabled (Olayinka-Agboola, Eke, & Ismail, 2025). At the macro-digital diffusion level, expanding telecommunications infrastructure significantly strengthens long-run data reliability and structural adjustment processes (Eke, Egwaikhide, Saheed, Alexander, Farouk, & Adeleke, 2019).

International evidence similarly confirms that forest recovery, water governance, and public environmental engagement exhibit strong positive co-movement in digitally enabled systems (Food and Agriculture Organization, 2020; OECD, 2020). Overall, the descriptive and correlation results confirm that Nigeria's ecosystem recovery is statistically coherent, digitally reinforced, and investment-sensitive, thereby providing a solid empirical foundation for the regression analysis that follows.

4.6 REGRESSION RESULTS AND COEFFICIENT INTERPRETATION

The Ordinary Least Squares (OLS) regression results provide strong empirical evidence on the determinants of ecosystem recovery in Nigeria over the period 2000–2024. The dependent variable, the Biodiversity Recovery Index, is significantly explained by a combination of biophysical, digital-social, and financial variables, confirming the multi-dimensional nature of ecosystem restoration.

The Forest Cover Index carries a positive and statistically significant coefficient, indicating that reforestation and reduction in deforestation are primary biological drivers of biodiversity recovery. This confirms that land-use regeneration remains the structural foundation of ecosystem restoration. Similarly, the Water Quality Index shows a strong positive and statistically significant effect, implying that improvements in surface and groundwater conditions directly enhance ecological resilience and species regeneration.

The Public Environmental Sentiment Index also exhibits a positive and highly significant coefficient, demonstrating that growing public awareness, pro-environmental attitudes, and digital civil engagement materially strengthen ecosystem recovery outcomes. This confirms the growing importance of social behavior and public pressure in shaping environmental performance. The Conservation Investment Index is likewise positive and statistically significant, validating the critical role of sustained ecological financing in restoring degraded systems.

The coefficient of social media Environmental Mentions is positive and statistically meaningful, indicating that digital visibility, online discourse, and environmental advocacy contribute to real restoration outcomes by reinforcing awareness, accountability, and policy responsiveness. In contrast, the Air Quality Index, while directionally positive, shows a weaker level of statistical significance, reflecting the slower adjustment dynamics of atmospheric systems compared to land and water ecosystems.

From a Nigerian digital-analytics perspective, advanced data systems and high-dimensional indicators significantly strengthen prediction accuracy and monitoring efficiency in complex environmental systems (Emmoh, Eke, Moses, & Ovre, 2025). Recent corporate-level and technology-driven governance studies further confirm that information transparency and digital monitoring substantially improve institutional performance and compliance outcomes (Olayinka-Agboola, Eke, & Ismail, 2025). Early ICT–environment interface studies in Nigeria also demonstrate that digital information systems significantly enhance coordination and long-run sustainability outcomes (Eke, 2015).

The overall goodness-of-fit of the model is high, indicating that variations in biodiversity recovery are substantially explained by the included biophysical, digital, and investment variables. Diagnostic indicators confirm the statistical reliability and stability of the estimated relationships. Globally, similar multi-factor environmental recovery models confirm that biodiversity restoration responds most strongly to land regeneration, public engagement, and sustained ecological investment (Dasgupta, 2021; Stern, 2007).

Overall, the regression results firmly establish that ecosystem recovery in the digital age is not purely a biological process but a socio-digital and investment-driven transformation.

Beyond the baseline regression estimates, the extended results show that ecosystem recovery in Nigeria follows a clear, digitally reinforced trend over the 2000–2024 period. A visual inspection of the time paths of the Biodiversity Recovery Index, Forest Cover Index, and Conservation Investment Index reveals three broad phases: a slow and fragile recovery phase (2000–2007), a transition and consolidation phase (2008–2014), and a digitally accelerated recovery phase (2015–2024). The last phase coincides with sharp increases in social media environmental mentions and public environmental sentiment, suggesting that digital awareness and online advocacy have become integral to the recovery process.

Robustness checks were conducted by re-estimating the model under alternative specifications, including (i) dropping individual explanatory variables, (ii) using reduced-form models with only biophysical and digital variables, and (iii) focusing on conservation investment and digital-sentiment interactions. Across all specifications, the signs and statistical significance of the core drivers—forest cover, water quality, public environmental sentiment and conservation investment—remain stable, confirming that the baseline relationships are not sensitive to variable omission or alternative functional forms. Social media mentions retain a positive and meaningful effect in the majority of these specifications, reinforcing their role as a complementary driver of recovery rather than a spurious correlate.

Diagnostic tests indicate no evidence of severe multicollinearity or debilitating serial correlation, and the explanatory power of the models remains high across robustness variants. This pattern is consistent with earlier Nigerian evidence showing that long-run digital and infrastructural variables exhibit stable relationships with development and sectoral performance outcomes (Eke, 2012; Eke, 2019b). At a broader digital-innovation level, predictive and data-intensive systems have been found to retain structural robustness when applied to complex resource and environmental processes (Kwaghtyo & Eke, 2023).

From a global perspective, the observed trend—where biophysical restoration gains momentum once conservation investments and public awareness reach critical thresholds—aligns with planetary boundary and climate–ecosystem assessments, which emphasize non-linear but structurally consistent recovery trajectories when sustained interventions are applied (Rockström et al., 2009; IPCC, 2021). The Nigerian evidence therefore supports the argument that ecosystem recovery is most durable when biological regeneration, conservation financing, and digital public engagement advance together over extended periods, rather than in isolation.

4.7 DISCUSSION OF FINDINGS

The findings of this study provide strong empirical confirmation that ecosystem recovery in Nigeria is a multidimensional process driven not only by biophysical restoration but also by digital public engagement and sustained conservation investment. The consistently positive and statistically significant effects of forest cover and water quality reaffirm the foundational role of core ecological variables in restoring biodiversity. These results align with classical ecological recovery theory, which posits that land regeneration and water system rehabilitation are primary transmission channels through which biodiversity rebounds in degraded environments.

Beyond the biophysical domain, one of the most significant contributions of this study lies in the confirmation of the socio-digital dimension of ecosystem recovery. The strong positive effect of public environmental sentiment and social media environmental mentions indicates that digital platforms now function as powerful mechanisms for shaping environmental behavior, mobilizing citizen action, and strengthening accountability in environmental governance. This confirms that ecosystem recovery in the digital age is increasingly co-produced by nature, institutions, and digitally engaged societies, rather than being driven by technocratic conservation policy alone.

The positive and significant role of conservation investment further demonstrates that financial commitment remains a critical binding constraint on environmental restoration. However, the interaction of conservation investment with rising public sentiment suggests that spending becomes more effective when reinforced by public awareness, digital visibility, and social pressure. This explains why periods of accelerated recovery in the dataset coincide with phases of both rising investment and heightened digital environmental engagement.

The weaker statistical influence of air quality on biodiversity recovery, relative to land and water indicators, reflects the slower and more complex atmospheric adjustment mechanisms associated with industrial emissions, transport pollution, and urbanization. This suggests that ecosystem recovery policies must differentiate between fast-adjusting ecological subsystems (land and water) and slow-adjusting systems (air and climate).

Taken together, the results strongly support the theoretical framework of the study, which integrates environmental externality theory, diffusion of innovation theory, and digital information governance. The Nigerian evidence clearly demonstrates that digital information flows and public sentiment act as amplifiers of ecological restoration efforts, while conservation investment provides the necessary financial backbone for long-run sustainability.

Overall, the discussion establishes that successful ecosystem recovery in Nigeria now depends on the strategic integration of biophysical restoration, digital public engagement, and sustained conservation financing within a coherent governance framework.

V. CONCLUSION

This study examined the long-run dynamics of ecosystem recovery over the period 2000–2024 by integrating biophysical environmental indicators with digital-social engagement and conservation investment. Using forest cover, air quality, water quality, and biodiversity recovery as core ecosystem outcome variables and applying Ordinary Least Squares regression techniques, the study provides robust empirical evidence that ecosystem recovery is jointly shaped by climate conditions, digital public participation, and sustained environmental financing.

The findings confirm that biophysical restoration remains the structural foundation of ecological recovery, particularly through sustained improvements in forest cover and water systems. Forest regeneration responds significantly to rising digital environmental engagement, confirming that digitally mediated public advocacy now plays an active role in reinforcing land-based restoration outcomes. Water quality similarly responds to increasing digital visibility and public monitoring,

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reflecting the growing effectiveness of citizen-driven accountability in local environmental governance.

However, the results further demonstrate that ecosystem recovery in the contemporary era extends far beyond purely biological processes. Digital engagement has emerged as a critical socio-institutional accelerator of ecological restoration. Social media environmental discourse and public sentiment, while varying in statistical strength across ecosystem components, consistently display positive directional influence, confirming that digital platforms increasingly shape environmental behavior, institutional responsiveness, and policy enforcement dynamics.

The study also establishes conservation investment as a decisive financial driver, particularly in the case of air quality improvement, where investment emerges as the dominant and statistically significant determinant. This highlights the capital-intensive nature of atmospheric restoration, which depends more heavily on large-scale infrastructural transformation than on decentralized public action. The slower response of air quality relative to forest and water systems further confirms the differentiated adjustment speeds of ecological subsystems and the necessity for sector-specific recovery strategies.

Most critically, the study identifies climate anomaly as the strongest structural constraint on biodiversity recovery. The significant negative impact of climate instability on the biodiversity recovery index confirms that rising climate stress materially undermines biological regeneration, even in the presence of increasing digital engagement and conservation spending. This finding underscores the centrality of climate stability as a prerequisite for long-term ecological resilience.

Overall, the study firmly establishes that ecosystem recovery in the digital age is not purely a biological process but a climate-sensitive, socio-digital, and investment-driven transformation. Sustainable environmental restoration therefore requires the strategic integration of biophysical rehabilitation, climate stabilization, digital public engagement, and sustained conservation financing within a coherent governance framework. The evidence generated in this study provides a robust empirical foundation for designing digitally enabled, investment-supported, and climate-responsive environmental policy for long-run ecosystem sustainability.

5.1 POLICY RECOMMENDATIONS

Based on the empirical findings of this study, several policy recommendations are proposed to strengthen ecosystem recovery in Nigeria through the synergistic integration of biophysical restoration, digital public engagement, and sustained conservation financing.

First, government should scale up nationwide reforestation and watershed restoration programmes, particularly in ecologically vulnerable regions. Since forest cover and water quality emerged as the strongest biological drivers of biodiversity recovery, land and water restoration must remain the core pillars of national environmental policy.

Second, environmental authorities should formally integrate social media analytics and digital reporting platforms into environmental monitoring and enforcement systems. Ministries, agencies, and state environmental protection bodies should adopt real-time environmental reporting dashboards that harvest citizen-generated data from digital platforms for early detection of deforestation, illegal mining, pollution incidents, and wildlife exploitation.

Third, sustained increases in conservation investment must be institutionalized through ring-fenced environmental financing mechanisms. Dedicated biodiversity trust funds, green bonds, climate finance facilities, and public–private conservation partnerships should be expanded to ensure predictable long-term funding for ecosystem restoration.

Fourth, government and civil society organizations should intensify national digital environmental literacy and awareness campaigns. Since public sentiment significantly reinforces recovery outcomes, environmental education must be deeply embedded within digital media strategies targeted at youths, SMEs, rural communities, and urban households.

Fifth, Nigeria should strengthen inter-agency data integration and open environmental data policies.

Effective ecosystem recovery requires seamless coordination among forestry, water resources, environment, meteorology, and digital economy institutions to improve data quality, transparency, and policy responsiveness.

Finally, climate-sensitive air-quality policies—covering transport emissions, energy generation, and industrial pollution—should be strengthened, given the slower atmospheric adjustment observed in the results. Together, these measures will ensure that ecosystem recovery in Nigeria remains biologically grounded, digitally amplified, and financially sustained.

Taken together, these policy measures will ensure that ecosystem recovery over the period 2000–2024 remains biologically grounded, digitally amplified, climate-resilient, and financially sustained, thereby positioning Nigeria for long-run environmental sustainability within a digitally enabled governance framework.

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