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Policy-Driven Approaches to Sustainable Microbial Conservation in Nigeria's Natural Resource Management

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Abstract

This review synthesizes the current state of knowledge and proposes a strategic framework for integrating microbial conservation into Nigeria's broader natural resource management agenda. It examines the fundamental roles microorganisms play in maintaining ecosystem services—including nutrient cycling, soil fertility, climate regulation, and water purification—within Nigeria's diverse biomes, from the derived savannahs to the Niger Delta. The paper highlights the significant knowledge and policy gap concerning microbial diversity in national conservation strategies, as evidenced by low public and professional awareness of biodiversity frameworks and the historical exclusion of microbes from global conservation instruments. Anthropogenic pressures such as charcoal production, deforestation, and pollution are shown to directly disrupt soil microbial communities and their critical functions, threatening system resilience. In response, this review advocates for a multifaceted and data-driven approach to microbial stewardship. Key recommendations include the adoption of microbial indicators for environmental monitoring, the urgent development of a national microbial database, the promotion of microbiome-based restoration techniques, and the implementation of robust policies and cross-sectoral education programs. Aligning with the mission of the IUCN's newly established Microbial Conservation Specialist Group (MCSG), this review positions the strategic conservation of Nigeria's microbial heritage as a non-negotiable foundation for achieving sustainable development, public health security, and ecological resilience in the face of environmental change.

Keywords: Microbial Conservation, Natural Resource Management, Ecosystem Services, Microbiome, Bioindicators.

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1. Introduction

Nigeria's natural resources are under immense and escalating pressure. With a population projected to exceed 400 million by 2050, the demands on its land, water, and biological systems are unprecedented (Izah *et al.*, 2025). The consequences are visible: deforestation for agriculture and charcoal production, land degradation, pollution of waterways, and a precipitous decline in biodiversity (Akindele et al., 2021). While conservation efforts have traditionally, and understandably, focused on charismatic fauna and critical habitats, a fundamental component of life has been almost entirely overlooked: the microbial world (Mueller *et al.*, 2025).

Microorganisms—bacteria, archaea, fungi, and protists—constitute the biological foundation of all ecosystems. They are the primary engineers of Earth's biogeochemical cycles, responsible for the decomposition of organic matter, nutrient mineralization, soil structure formation, and climate-relevant gas fluxes (Jiang *et al.*, 2022). In Nigeria's specific context, soil microbes determine the fertility of agricultural lands, aquatic microbes influence water quality and fisheries, and plant-

associated microbes underpin the health of forests and the productivity of crops (Adeyemo *et al.*, 2025). Despite their ubiquity and irreplaceable functions, microbial communities and their diversity remain critically underrepresented in Nigerian conservation science, policy, and public awareness (Akindele *et al.*, 2021; Olabode *et al*., 2020).

The establishment of the **International Union for Conservation of Nature (IUCN) Microbial Conservation Specialist Group (MCSG)** in 2025 marks a pivotal moment, formally acknowledging that "conservation cannot succeed without assessing and protecting the microbial communities that sustain biodiversity, ecosystem function, and human health" (Mueller *et al.*, 2025). This global mandate necessitates a localized response. Therefore, this review aims to bridge the significant gap between the recognized global importance of microbial conservation and its practical application within Nigeria's unique environmental and socio-economic landscape. We argue that **sustainable management of Nigeria's natural resources is unattainable without explicit strategies to conserve the microbial communities** that sustain them. This document provides a schematic review to guide policymakers, researchers, and conservation practitioners toward integrating microbial stewardship into Nigeria's national development agenda.

2. The State of Microbial Systems in Key Nigerian Biomes

2.1. Soil Ecosystems: The Impact of Land-Use Change

Soil microbiomes are the engine rooms of terrestrial ecosystems. In Nigeria, they face severe disruption from practices like charcoal production, a major driver of deforestation and land degradation. A 2025 study in the derived savannah of southwestern Nigeria provided a stark, data-rich illustration of this impact (Adeyemo *et al*., 2025). The research found that soils from Charcoal Production Sites (CPS) exhibited significantly higher microbial biomass phosphorus and elevated activity of key enzymes (Phosphatase, Thiosulfate dehydrogenase) compared to Non-Production Sites (NPS). While this may initially suggest increased activity, it is indicative of a **severely disrupted and simplified ecosystem**. The burning process eliminates much of the native microbial community, creating a barren environment subsequently colonized by a narrow cohort of opportunistic, often bacterial, taxa specializing in breaking down the remaining charred organic matter (Adeyemo *et al.*, 2025). This shift represents a loss of functional diversity and redundancy, making the system less resilient. Furthermore, the study noted altered profiles of crucial micronutrients (Mn, Zn, Cu, Co, Fe), which are cycled by microbes, highlighting a cascade effect on overall soil chemistry and long-term fertility (Adeyemo *et al.*, 2025).

2.2. Aquatic Ecosystems: Pollution and Public Health

Nigeria's freshwater and coastal systems are repositories of immense microbial diversity essential for nutrient cycling and water purification. However, they are also the ultimate sinks for pollution, making them hotspots for microbial risk. Pathogenic contamination from inadequate sanitation is a profound public health burden, with waterborne diseases like cholera and typhoid remaining endemic (Izah *et al.*, 2025). Emerging research underscores the value of **predictive modeling and microbial source tracking** as conservation *and* public health tools. By analyzing microbial community structures—such as the ratios of specific bacterial groups—scientists can identify contamination sources (e.g., human sewage vs. agricultural runoff) and model the dynamics of pathogen outbreaks in relation to climatic events like flooding (Izah *et al.*, 2025). This transforms microbial data from a simple pollution snapshot into a predictive dashboard for pre-emptive resource management and health protection, an approach desperately needed for Nigeria's stressed waterways (Izah *et al*., 2025).

2.3. Forest and Agroecosystems: From Biodiversity Hotspots to Farmland

Nigeria's remaining forests, such as those in the Niger Delta and Cross River regions, harbor unique and understudied microbiomes intimately linked to tree health, carbon storage, and overall ecosystem stability. Deforestation for timber, agriculture, or urbanization doesn't just remove trees; it extirpates the complex below-ground microbial networks those trees co-evolved with, potentially forever (Mueller *et al.*, 2025). The conversion to agriculture imposes a new regime. Microbial communities shift from diverse, forest-specialist consortia to assemblages dominated by taxa tolerant of disturbance, fertilizer inputs, and pesticides. This "homogenization" of microbiomes is a silent crisis, reducing the genetic reservoir available for ecosystem adaptation to future stresses like novel pests or climate shifts (Jiang *et al*., 2022). The loss of beneficial plant-growth-promoting rhizobacteria and mycorrhizal fungi also directly undermines soil health and crop resilience, creating a dependency on chemical inputs.

3. Barriers to Microbial Conservation in Nigeria

Knowledge and Awareness Gap: A foundational barrier is the profound lack of awareness and understanding of microbial diversity's value. A 2021 national survey revealed that awareness of Nigeria's own National Biodiversity Strategy and Action Plan (NBSAP) was low even among professionals (43.8%), and very low among non-professionals (12.1%) (Akindele *et al.*, 2021). If general biodiversity awareness is this limited, public and policymaker understanding of *microbial* biodiversity is virtually nonexistent. This translates into a lack of political will and public demand for conservation initiatives targeting invisible life.

Policy and Institutional Neglect: Historically, global and national conservation frameworks have been "macrobe-centric." As noted in a 2025 editorial, major frameworks like the Convention on Biological Diversity (CBD) and even the One Health approach have "largely overlooked environmental microbial communities" (Mueller *et al.*, 2025). Nigeria's existing environmental laws and policies are often described as non-pragmatic, lacking scientific foundation, and poorly enforced (Olabode *et al*., 2020). They contain no provisions for assessing, monitoring, or conserving microbial resources, creating a legal vacuum.

Scientific and Data Deficit: There is a critical shortage of baseline data on Nigerian microbial diversity across different biomes, seasons, and land-use types. This makes it impossible to assess trends, identify threatened microbial communities, or measure the impact of interventions. The call for a **data-driven policy approach** (Olabode *et al.*, 2020) is stymied by the

absence of the very data required to drive it. Research capacity in environmental microbiology is also limited, with few dedicated research programs or funding streams.

Anthropogenic Pressure and Socio-Economics: The drivers of microbial loss are the same as those for macrobial loss, but often more acute. Poverty and population growth lead to unsustainable practices like rampant charcoal production (Adeyemo *et al.*, 2025). Pollution from industrial and domestic waste directly toxifies microbial habitats. These socio-economic root causes make purely technological conservation solutions insufficient.

4. A Strategic Framework for Sustainable Microbial Conservation

To overcome these barriers, we propose a multi-pronged strategic framework aligned with the core functions (Assessment, Planning, Action, Networking, Communication) of the IUCN MCSG (Mueller *et al.*, 2025).

Pillar 1: Assessment and Knowledge Creation

Establish a National Microbial Observatory Network: Deploy standardized sampling across a network of protected areas, agricultural zones, and impacted sites (e.g., near charcoal production) to create longitudinal datasets on microbial community composition and function (Adeyemo *et al.*, 2025; Jiang *et al.*, 2022).

Develop Nigeria-Specific Microbial Indicators: Research and validate microbial taxa or genetic markers that serve as reliable bioindicators for soil health (e.g., post-disturbance recovery), water pollution, and the success of restoration projects (Jiang *et al.*, 2022).

Conduct a National Microbial "Bioblitz": Mobilize researchers to conduct a coordinated effort to catalogue microbial diversity in key biodiversity hotspots, creating a foundational species inventory.

Pillar 2: Policy Integration and Planning

Revise the National Biodiversity Strategy and Action Plan (NBSAP): Explicitly integrate microbial diversity as a core component of Nigeria's biodiversity targets, with specific objectives and indicators.

Mainstream Microbes into Existing Programs: Incorporate microbial health metrics into the management plans of national parks, the criteria for designating protected areas, and the monitoring protocols for agricultural and water resource schemes.

Pilot Microbial Impact Assessments: Require the assessment of impacts on soil and water microbiomes as part of the Environmental Impact Assessment (EIA) process for major development, mining, and agricultural projects.

Pillar 3: On-the-Ground Action and Innovation

Promote Microbiome-Aware Restoration: Move beyond simply planting trees to include soil microbiome restoration techniques, such as using inoculants of native mycorrhizal fungi and bacteria to improve seedling survival and ecosystem recovery rates (Mueller *et al.*, 2025).

Explore Bio-Prospecting for Sustainable Solutions: Responsibly research and utilize native microbial strains for bioremediation of oil-polluted sites in the Niger Delta, for developing biopesticides/biofertilizers to reduce chemical use, and for enhancing waste treatment.

Support Community-Based Sustainable Practices: Develop incentives and support systems to transition communities away from highly destructive practices like unsustainable charcoal production (Adeyemo *et al.*, 2025) toward microbial-friendly agroforestry and conservation agriculture models.

Pillar 4: Capacity Building, Communication, and Networking

Launch a Public Engagement Campaign: Translate the "microbial conservation" message into relatable concepts for farmers, pastoralists, community leaders, and students, emphasizing the link between healthy microbes, productive soil, clean water, and health.

Strengthen Scientific and Technical Capacity: Invest in training a new generation of Nigerian environmental microbiologists and biotechnologists, and equip key national laboratories with modern sequencing and bioinformatics capabilities.

Foster Cross-Sectoral Collaboration: Create a formal Nigerian Microbial Conservation Network linking government ministries (Environment, Agriculture, Water Resources), academia, NGOs, and community groups to share data, align strategies, and advocate collectively (Olabode *et al.*, 2020).

5. Conclusion

The path toward sustainable management of Nigeria's natural resources must be rerouted to include the unseen majority of life that makes those resources function. **Microbial conservation is not a peripheral scientific concern but a central pillar of national food security, water safety, public health, and climate adaptation.** The strategies outlined here—from systematic assessment and policy reform to community-driven action—provide a viable schematic for action. The recent global recognition by the IUCN provides an unprecedented opportunity for Nigeria to become a regional leader in this emerging field. By investing in the health and diversity of its microbial foundations, Nigeria can build more resilient ecosystems, a more sustainable economy, and a healthier population. The time to act is now; the life we cannot see is the life upon which all visible life absolutely depends.

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